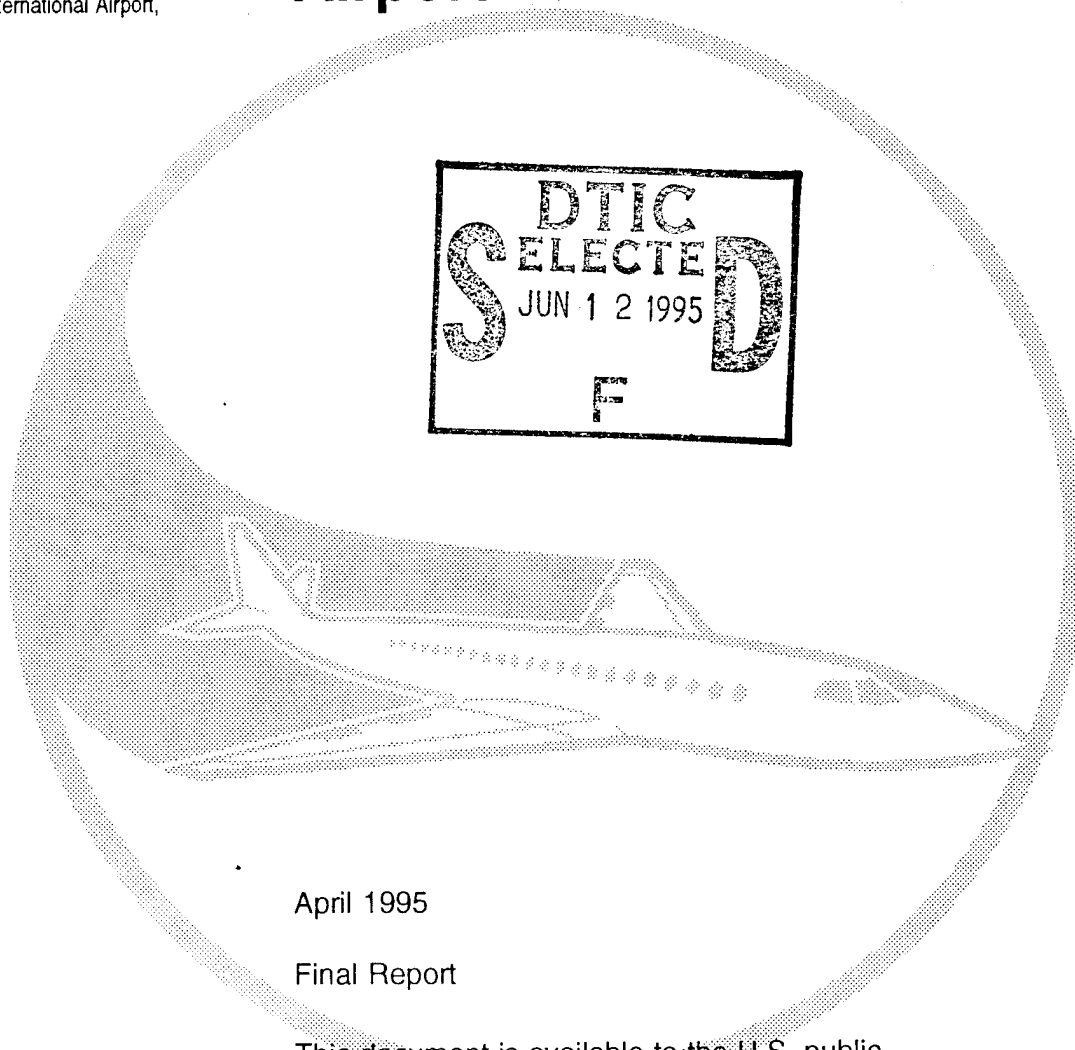
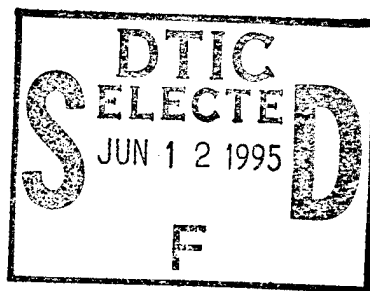


DOT/FAA/CT-94/53

FAA Technical Center
Atlantic City International Airport,
N.J. 08405

Joint Sealants for Airport Pavements



April 1995

Final Report

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1. Report No. DOT/FAA/CT-94/53		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Joint Sealants for Airfield Pavements				5. Report Date April 1995	
				6. Performing Organization Code	
7. Author(s) Larry N. Lynch and J. Kent Newman				8. Performing Organization Report No.	
9. Performing Organization Name and Address US Army Corps of Engineers, Waterways Experiment Station Geotechnical Laboratory, 3909 Halls Ferry Road Vicksburg, MS 39180				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. DTFA01-90-Z-02069	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405				13. Type of Report and Period Covered Final Report October 1991 - December 1993	
				14. Sponsoring Agency Code AAR-410	
15. Supplementary Notes The US Army Corps of Engineers, Waterways Experiment Station, conducted this study as part of the Interagency Agreement Project titled: "Durability Criteria for Airport Pavements." The FAA Contracting Officer's Technical Representative (COTR) was Dr. Satish K. Agrawal.					
16. Abstract The objective of this study was to evaluate the field performance of five different types of pavement joint sealant materials at five different airports located in varying climatic regions. Each of the sealant materials was installed at all five airports. The same contractor was used to install the sealants at each of the five airports and the same lot number of the various sealants was installed at each airport. The sealants were stored in a temperature controlled warehouse until they were needed at the job site and 100 percent inspection was provided at each airport. These controls helped to minimize any variations in the service life of the sealants that were not material related. Differential Scanning Calorimetry and Fourier Transform Infrared Spectroscopy were investigated as potential laboratory analysis techniques for joint sealants. The results of the field evaluations indicate the conformance of a sealant material to an appropriate material specification does not automatically signify satisfactory field performance; different types of sealants do perform differently based upon climatic exposure; and no revisions are necessary to procedures listed in the FAA Item P-605 for joint sealing projects. The research delineated the fact that material characterization procedures are needed for pavement joint sealants. These types of procedures could be used in material specifications that would be more indicative of sealant performance.					
17. Key Words Fourier Transform Infrared Spectroscopy Differential Scanning Calorimeter Silicone Based, Coal Tar Based Polysulfide Based, Pavement Sealants			18. Distribution Statement This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 149	
				22. Price	

PREFACE

This project was sponsored by the Federal Aviation Administration (FAA) as Task 5 "Joint Sealants for Airport Pavements" of the Durability Criteria for Airport Pavements, Inter-agency Agreement No. DTFA01-90-Z-02069. The contractor for the project was Scodeller Construction, Inc. (contract number DACA39-92-C-0003). The reporting period was from October 1991 to December 1993. The project was conducted by the Pavement Systems Division (PSD), Geotechnical Laboratory (GL) of the U.S. Army Engineer Waterways Experiment Station (WES). Dr. Satish Agrawal, Airport Technology Branch, ACD-110, was the FAA Technical Monitor.

The project was conducted under the general supervision of Dr. W. F. Marcuson III, Director, GL, WES, and under the direct supervision of H. H. Ulery, Jr., former Chief, PSD, GL; Dr. G. M. Hammitt II, Chief, PSD; and Mr. T. W. Vollor, Chief, Materials Research and Construction Technology Branch (MRCT). The WES Principal Investigator was Mr. Larry N. Lynch. Mr. Lynch and Dr. Kent Newman wrote the report. Mr. Herbert McKnight conducted all American Society for Materials and Testing (ASTM) and Federal Specification conformance testing of the sealant materials, and Messrs. Roger Graham and Charles Dorman conducted the laboratory evaluations of the field samples. Messrs. Dewey White and Roger Graham conducted all of the field evaluations.

The following personnel significantly contributed to the successful completion of this FAA project; Mr. Dave Bacci of Scodeller Construction, Inc. (the contractor representative during the joint sealing project); Messrs. Robert Brancheau, Ron Curet, Philip Eastberg, Todd Anderson, and Louis Cruz of the Greater Orlando Aviation Authority; Messrs. Lance Dutton, Rod Savini, Steven Richard, and Gary Litzsinger of Airport Authority of Washoe County; Messrs. Carl Rodolph, Barry Kamhoot, and Ben Trujillo of Albuquerque International Airport; Messrs. Thomas Boswell, Mike Fulghum, and Joe Meador of the Metropolitan Nashville Airport Authority; and Messrs. Lew Palmer, William Langworth, and LTC Lou Nigro of the Selfridge Air National Guard Base.

The Director of WES during the preparation and publication of this report was Dr. Robert W. Whalin. The Commander and Deputy Director was COL Bruce K. Howard, EN.

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METRIC CONVERSION FACTORS

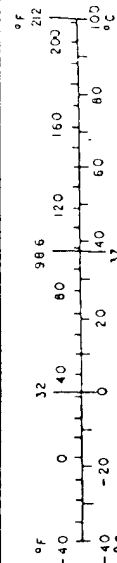
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.46	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tblsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in. = 2.54 exactly. For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SO Catalog No. C13.110-286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



EXECUTIVE SUMMARY

The less than satisfactory field performance of pavement joint sealant materials is becoming a greater concern to pavement engineers as they attempt to maintain infrastructure systems with reduced maintenance funds. Joint sealant materials have long been used as a method to extend the life of a pavement, but if the sealants prematurely fail, the goal of using that sealant has been defeated.

Research studies conducted in the 1980's by the Naval Civil Engineering Laboratory (NCEL) and the United States Army Engineer Waterways Experiment Station (WES) indicated that pavement joint sealant failures could generally be associated with inadequate materials (i.e., the material does not conform to the appropriate specification or the wrong material was selected for the application), poor workmanship (i.e., the joints were not properly prepared before sealant installation or the sealant material was not properly handled during installation), or improper design and inspection (i.e., the correct shape factor was not specified or project requirements were waived). Based upon the conclusion of these two studies, the Federal Aviation Administration (FAA) tasked WES to conduct a research effort that would attempt to address the arguments commonly used when joint sealant materials fail as well as provide actual life cycle data for various types of sealant materials in differing climatic regions.

The overall approach used for the project was to select five different types of field-molded joint sealants and install these materials into the joints at five different airports located in different climatic regions throughout the United States. The selection of different climatic regions would allow the determination of climate effect on sealant performance. The five sealants selected for the investigation were Crafco Superseal 1614A (a hot-applied coal tar based sealant), Dow Corning® 888SL (a self-leveling silicone based sealant), Koch Materials Product 9012 (a hot-applied coal tar based sealant), Koch Materials Product 9015 (a two-component polysulfide based sealant), and Koch Materials Product 9050SL (a single-component polysulfide-based sealant). The five climatic regions selected for the project were wet-no freeze (Orlando, Florida), wet-freeze-thaw (Nashville, Tennessee), wet-freeze (Mount Clemens, Michigan), dry-freeze (Reno, Nevada), and dry-freeze-thaw (Albuquerque, New Mexico).

The argument of material deficiencies was addressed by testing the five sealants that were to be used on the project to the appropriate material specification. Differential Scanning Calorimetry (DSC) and Fourier Transform Infrared Spectroscopy (FTIR) were conducted in addition to the specification testing. The argument concerning inadequate project specifications was addressed by developing the project specifications using FAA Item P-605 and the Corps of Engineers Guide Specification (CEGS) 002593

coupled with 100 percent inspection of each project. The 100 percent inspection combined with a training meeting with the contract personnel addressed the poor construction practices concern. In addition the same contractor personnel were used at each location to minimize variability in construction procedures. Field evaluations were conducted at approximately six months and one year after installation to observe the condition of the sealant materials.

The field evaluations indicated that silicone materials can potentially be used successfully in most climatic regions. The cost of preparing the joints was the same regardless of the sealant type used. Therefore, the service life of the silicones must be approximately 1.2 times that of the of hot-applied, coal tar based materials to be economically competitive. The two hot-applied coal tar materials performed somewhat satisfactorily in the wet-no freeze, wet-freeze-thaw, and the wet-freeze climates. The remaining two materials, the two-component polysulfide and the single-component polysulfide, did not perform as well as the other materials. Part of the problems associated with the performance of the two-component material were associated with the installation equipment and some of the performance problems associated with the single-component polysulfide material could have been caused by the fact that the shelf life of the material was close to expiration.

The laboratory analysis indicated that all of the materials conformed to the appropriate material specification. The DSC results indicated that there was a difference in the glass transition temperatures for the various sealants but changes in the glass transition temperature associated with ageing could not be detected. The FTIR analysis also could not detect changes in chemical compositions due to aging. It is expected that the lack of detecting changes caused during the aging of the sealant was caused in part by the sample preparation techniques. Additional research is needed in the material characterization of pavement joints sealants. A more in-depth investigation using the DSC and FTIR as well as techniques such as dynamic shear rheology, nuclear magnetic resonance, and mass spectrometry could greatly assist in the development of performance models for pavement joint sealants.

Field evaluations at each of the airports should be continued every six months or at least on a yearly basis until all of the sealant test sections require resealing. This would allow more accurate life cycle costs to be determined.

INTRODUCTION

PURPOSE.

The purpose of this research was to investigate three identified areas which were suspected of contributing to the poor field performance of field-molded pavement joint sealants: inadequate materials, poor workmanship, and inadequate design. The procedure used to complete the investigation was to select five different types of field-molded pavement joints sealants and have one contractor install the five sealants at five different airports throughout the United States. This approach would allow determination of the effects of climatic conditions on the performance of the sealants, thereby providing an indication of realistic life-cycle costs for the various sealant types versus climate as well as determining if the current specifications used by the Federal Aviation Administration (FAA) are appropriate to achieve satisfactory sealant performance.

BACKGROUND.

The less than satisfactory field performance of pavement joint sealant materials is becoming a greater concern to pavement engineers as they attempt to maintain infrastructure systems with reduced maintenance funds. Joint sealant materials have long been used as a method to extend the life cycle of a pavement, but if the sealants prematurely fail, the goal of using that sealant has been defeated.

The premature failure of joint sealant materials led to an FAA sponsored research effort designed to determine the failure mechanisms of pavement joint sealants. The research effort was conducted from 1986 to 1988 by the Naval Civil Engineering Laboratory (NCEL) and consisted of both laboratory and field investigations of airport pavement joint sealants (Inaba, Hironaka, Novison, 1988). The objectives of the NCEL research effort were to determine the essential characteristics required for a sealant material to perform satisfactorily in portland cement concrete (PCC) pavements by conducting laboratory analysis and field evaluations.

During the same timeframe as the FAA research effort, the USAE Waterways Experiment Station (WES) was conducting a pavement joint sealant research effort which was cosponsored by the Headquarters, U.S. Army Corps of Engineers and the U.S. Air Force Engineering Services Center (AFESC) (Lynch, 1989). The research effort conducted by WES also focused on laboratory and field evaluations to determine why sealant materials that allegedly conform to the appropriate material specification and were properly installed into the joints were not providing satisfactory performance.

The two studies had slightly different objectives but they both concluded that joint sealant failures in the field could not be conclusively attributed to one factor. The failure could generally be related to inadequate materials (i.e., the material does not conform to the appropriate specification or the wrong material was selected for the application), poor workmanship (i.e., the joints were not properly prepared before sealant installation or the sealant material was not properly handled during installation), or improper design and inspection (i.e., the correct shape factor was not specified or project requirements were waived). The major difference between the NCEL and WES projects was the emphasis of the conclusions. NCEL placed the emphasis of their conclusions on material deficiencies being the most probable cause of sealant failures. The WES investigation concluded that a relationship between specification conformance and field performance cannot be determined because most sealant materials are not tested for material specification conformance, and inspection during the sealing project is typically less than satisfactory.

The conclusions from both the NCEL and WES studies reiterate common arguments that occur during and after a joint sealing project when the sealants fail. A contractor will often state that the cause of a sealant's poor field performance is either inferior materials or an inadequate project specification. A manufacturer on the other hand will cite workmanship or the project specifications and the user agency will, of course, cite workmanship or material deficiencies. The arguments are commonplace but verification of which argument, if any, is correct for a particular project is often difficult because either the sealant materials were not independently tested, the project specifications were not actually followed, and/or there was a lack of inspection during the project. Based upon the conclusion of these two studies, the FAA tasked WES to conduct a research effort that would attempt to address the arguments commonly used when joint sealant materials fail as well as provide actual life cycle data for various types of sealant materials in differing climatic regions.

PROJECT APPROACH.

The overall approach used for the project was to select five different types of field-molded joint sealants and install these materials into the joints at five different airports located in different climatic regions throughout the United States. The sealants would be tested for compliance to the appropriate material specification and each project site would have 100 percent inspection.

Before the sealant materials or the airport locations could be selected, it was necessary to specifically outline how each of the arguments used to explain poor field performance would be addressed. The first argument dealt with the possibility of material deficiencies. It would therefore be necessary to test all sealants

that were to be used on the project to the appropriate material specification. The material specifications used for this study were ASTM D 3569 (ASTM, 1985a), ASTM D 3581 (ASTM, 1985b), and Federal Specification SS-S-200. Originally, FAA Engineering Brief 36 modified for self-leveling materials (FAA, 1986) was to be used for specification testing of the single-component, cold-applied, self-leveling sealants. However, due to concerns expressed by manufacturers of the selected cold-applied, single-component materials, the specific manufacturer's material specification test procedures were used. These specifications were selected because they represent the types of sealant materials on which the FAA desired additional information. None of the selected sealants would be installed at the airport locations if they did not meet the appropriate material specification. Additional laboratory tests were conducted on the sealants in the as-received condition and on samples taken from the field. These additional tests were conducted in an effort to obtain a more in-depth understanding of the physical changes that may occur during the service life of the sealant.

Inadequate project specifications was the second argument often used to explain poor field performance of sealants. The WES study and conversations with personnel involved with joint sealing projects indicated that often the project specifications were not closely followed with respect to the amount of cleaning required during joint preparation. To address this issue, the project specifications were established using FAA Item P-605 (FAA, 1988), and the Corps of Engineers Guide Specification (CEGS) 002593 (CEGS, 1989). These specifications are used to produce project specifications for various user agencies and closely follow joint preparation procedures and cleanliness requirements recommended in many of the joint sealant manufacturer's product literature.

To ensure the specified procedures were followed, the same contractor was used at all five locations, the same lot number or batch number of each sealant was used at all five airports, and the projects were 100 percent inspected. The requirement that the same contractor perform the work in all five locations, and the 100 percent inspection addressed the argument concerning workmanship.

To eliminate as many variables as possible, the purchased sealants were stored in a temperature controlled area at WES until they were required in the field, the same batch or lot number of each of the selected sealants was used at all five locations, and the joint configuration at all locations were as similar as possible. Each project site consisted of approximately 10,000 linear feet of sealed joints. Approximately 5,000 linear feet of those joints were located in a taxiway area and 5,000 linear feet were located in a parking apron or gate area. For example, the two small highlighted blocks in figure 1 illustrate the locations of the joint sealant sections at the Metro Nashville Airport, one of

the selected airports. Concourse C was selected as the area where the joints would likely receive fuel spillage and Taxiway C-9 at the end of Runway 31 R/W was selected for the non fuel spillage area. Figure 2 provides a close up view of the pavement around Concourse C that was sealed during the project. Figure 3 provides a close up view of Taxiway C-9. These figures illustrate the typical pattern used for each section and the numbers used in Figures 2 and 3 represent the sealant that was installed in that area. The sealant location at each of the five airports was selected so that the materials would be exposed to the same type of traffic and environmental conditions at the particular airport. The joint sealant locations at the other airports are provided in appendix A.

The last phase of the research was the field performance evaluation of the materials. The evaluations were conducted in both winter and summer months so the sealant could be examined in extension and compression. The evaluations were then used to assist in determining which type or types of sealant materials perform best in each climate.

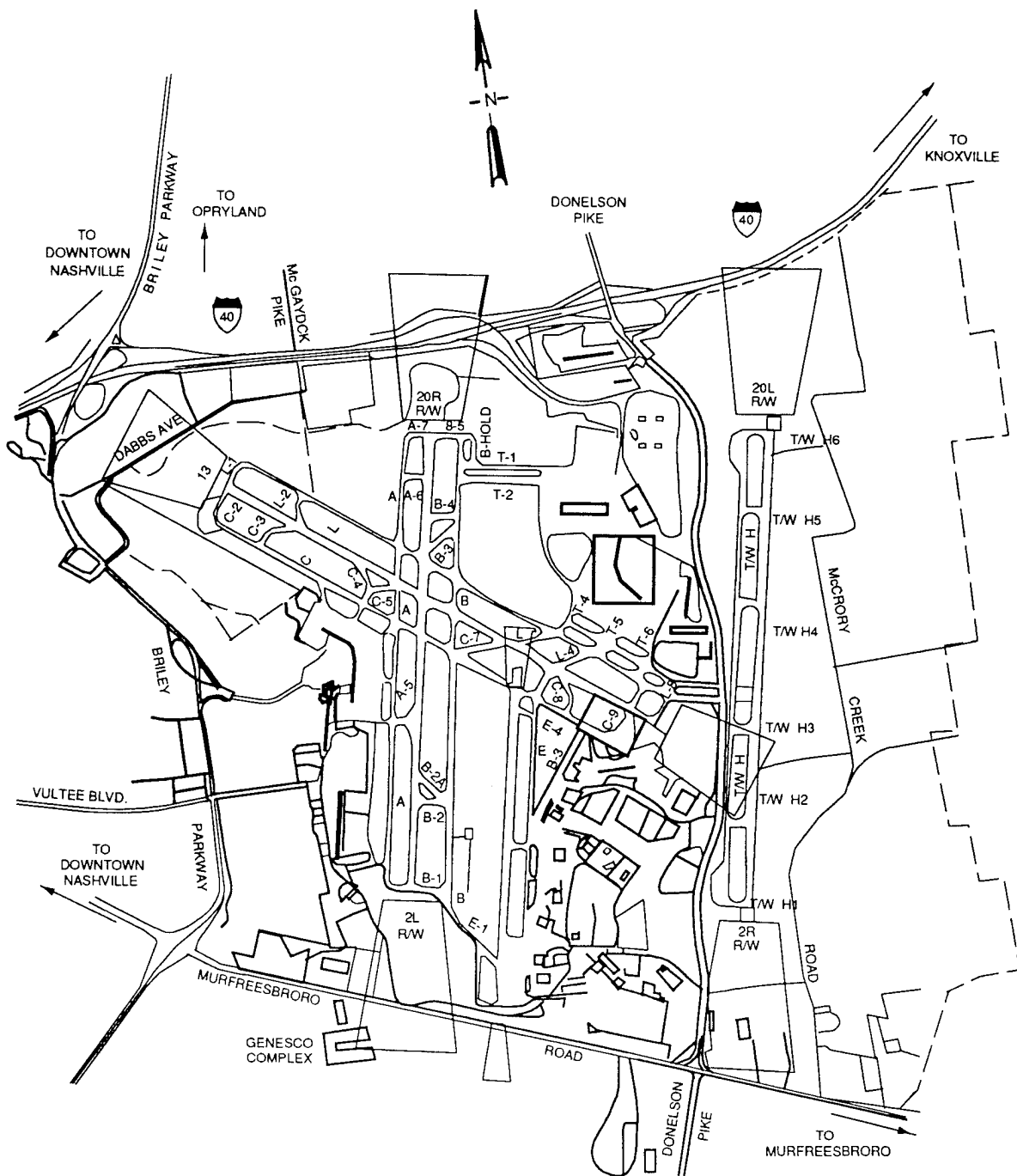


Figure 1. Site Map of Metro Nashville Airport.

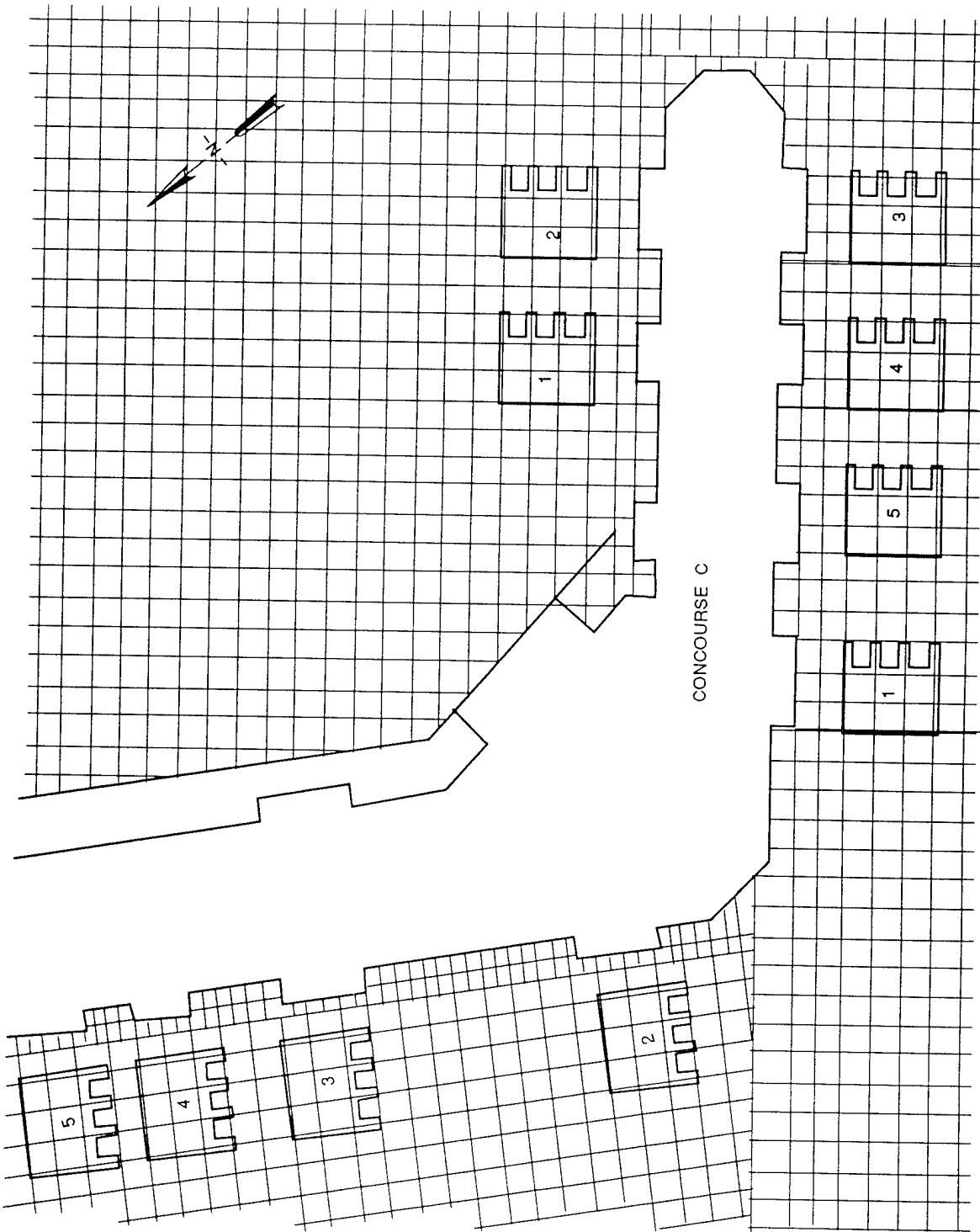


Figure 2. Concourse C at the Metro Nashville Airport
(numbered blocks indicate areas sealed)

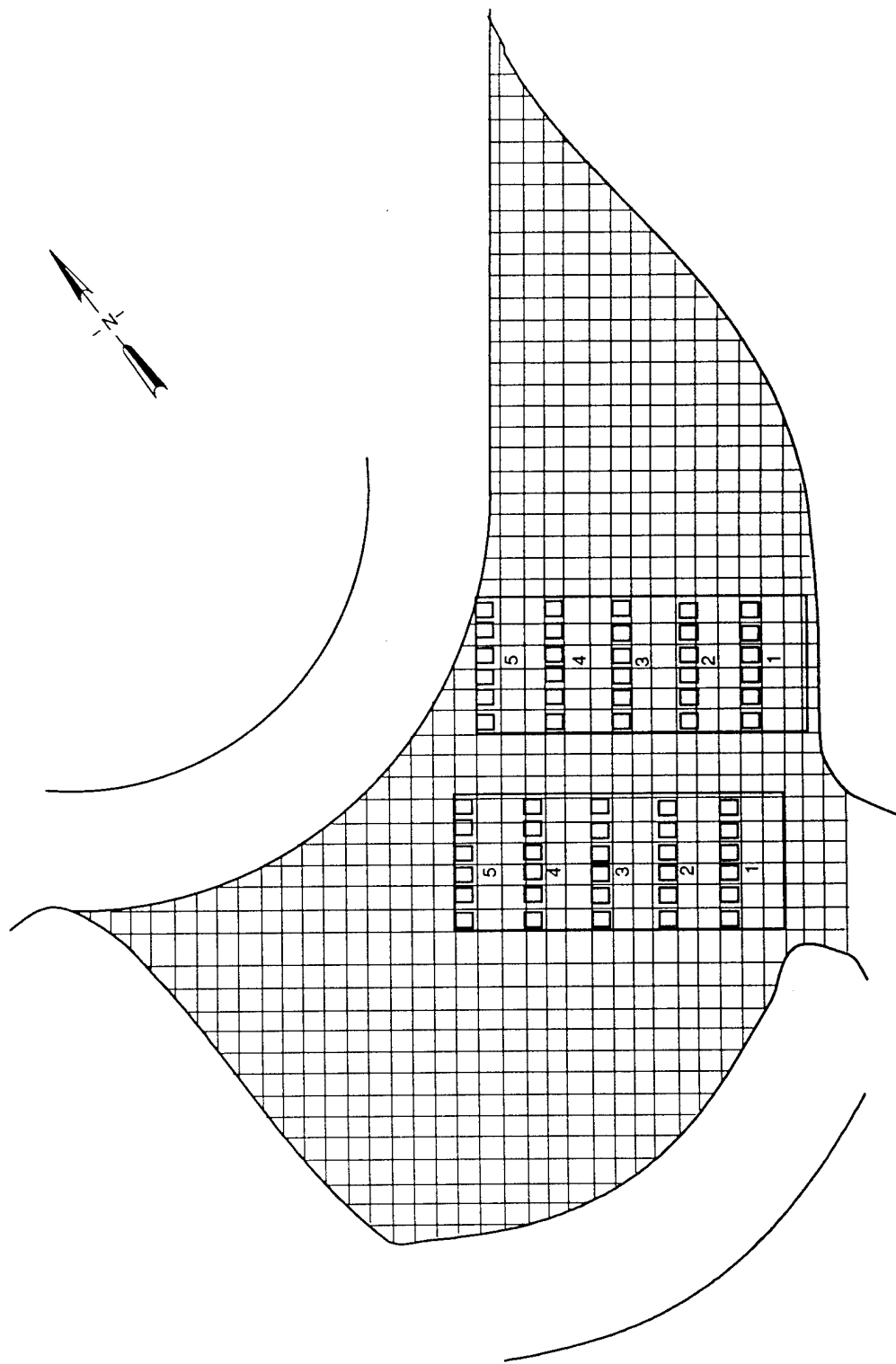


Figure 3. Area C-9 at the Metro Nashville Airport.

SEALANT SELECTION

The selection of the five sealants was based on recommendations from the NCEL study, historical test data from WES, requirements from the FAA concerning specific sealants, and the requirement that the sealants would be used for maintenance activities instead of new construction. Based on these criteria the five sealants which were selected are as follows:

a. Dow Corning® 888SL, a self-leveling silicone sealant which was tested in accordance with the manufacturer's recommended material specification.

b. Koch Materials Product 9012, a hot-applied, jet-fuel-resistant sealant which was tested in accordance with Federal Specification SS-S-1614A and ASTM D 3569.

c. Crafcro Superseal 1614, a hot-applied, jet-fuel-resistant sealant which was tested in accordance with Federal Specification SS-S-1614A and ASTM D 3581.

d. Koch Materials Product 9015, a two-component, cold-applied, jet-fuel and blast resistant sealant which was tested in accordance with Federal Specification SS-S-200E.

e. Koch Materials Product 9050SL, a single-component, self-leveling, cold-applied polysulfide material which was tested in accordance with the manufacturer's recommended material specification and fuel-resistance criteria of ASTM D 3569.

Dow Corning® 888 was originally recommended for use in field evaluations by NCEL in its study; however, the FAA was interested in self-leveling materials and so the 888SL material was selected. The Koch Materials Product 9012 and Product 9015 and the Crafcro Superseal 1614 were selected based on historical laboratory data at WES. These materials had all been tested on more than 20 different occasions and they each had the highest overall passing percentage of all the materials in the WES data base for their particular type. The Koch Materials Product 9050SL was selected because it is a single-component, self-leveling, cold-applied sealant which exhibits resistance to fuel spillage as described by criteria in ASTM D 3569.

The selection of these sealants does not imply that other sealants with similar physical characteristics are not acceptable for use on projects nor does it imply that the selected sealants should be ever specified by name in future projects. The data obtained during the field evaluations should be used instead as a guide in selecting which type, i.e., ASTM D 3569, ASTM D 3581, etc., of sealant should be specified in specific climatic regions of the United States.

The specific test and criteria requirements for the material specifications used to determine if the sealants were acceptable for installation at the different airports are provided in tables 1 through 7 in the LABORATORY ANALYSIS section. The summarized test results for each of the sealants are provided in tables 8 through 12.

SITE SELECTION

Three major factors were used in considering which airports should be selected for the field evaluation of the sealant materials. The factors were:

a. The airports had to be located in differing climatic regions.

b. The airport had to have a large quantity of PCC pavement; this research effort would not involve asphalt pavement crack sealing.

c. The airport had to be willing to participate in the field evaluations; not every airport that was approached wanted to participate.

Figure 4 taken from Peterson (Peterson 1982), was used to define the climatic regions and to ensure that the airports selected were in different climatic regions. The climatic regions which were selected are not necessarily the most severe, but they are the ones which cover 80 to 90 percent of the United States. Therefore, the sealant performance in these climatic regions may be more representative to other areas in the United States.

Once the climatic regions had been selected, telephone inquiries were made to various airport authorities to determine the quantity of PCC pavements at their location and their willingness to participate. From these conversations, the following airports were selected for the field evaluations:

a. Orlando International Airport which is located in a wet-no freeze climate.

b. Metro Nashville Airport which is located in a wet-freeze-thaw climate.

c. Selfridge Air National Guard Base, Mount Clemens, Michigan, which is located in a wet-freeze climate.

d. Reno-Cannon Airport which is located in a dry-freeze climate.

e. Albuquerque International Airport which is located in a dry-freeze-thaw climate.

Originally, Chicago-O'Hare International Airport was selected instead of Selfridge Air National Guard Base, but contract and scheduling difficulties prevented the use of Chicago-O'Hare.

The contract for the field installation of the sealant materials was awarded in September 1991 and the contractor was

given the notice to proceed in April 1992. The work schedule was coordinated between WES, the contractor, and the individual airports.

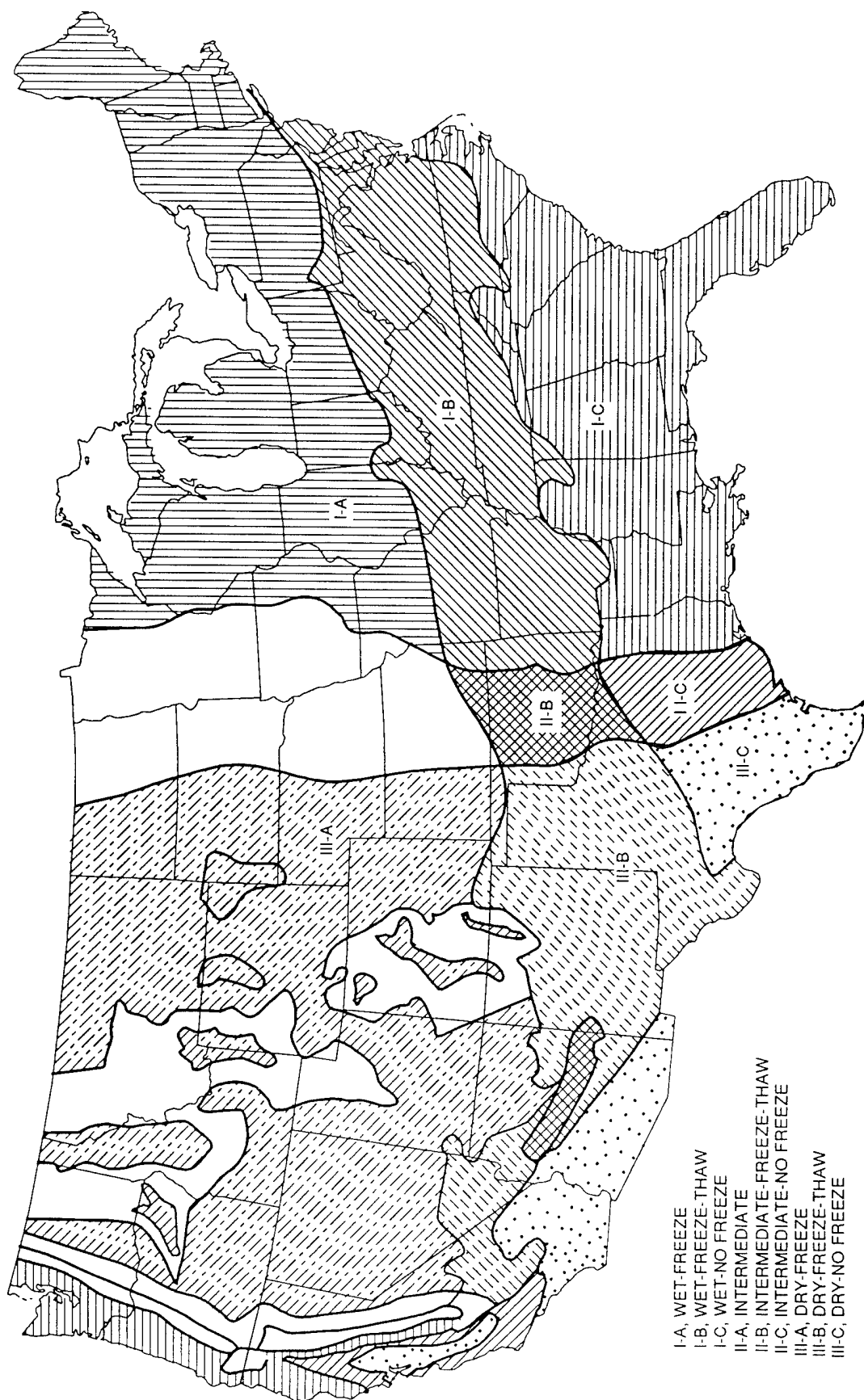


Figure 4. Climatic Regions of the United States
Taken from page 23 of NCHRP-SHP 98 (Peterson, 1982).

SEALANT INSTALLATION

The procedures used to prepare the joints and install the sealant at each of the locations were similar. Variations in joint widths and joint configurations necessitated some site specific modifications to the procedures. In general, these modifications were not departures from the technical requirements of the specification but were made to expedite the process and to better prepare the joints.

The equipment included in the specification (a more detailed description is located in appendix B) to prepare the joints and install the sealant included:

a. Tractor-mounted routing tool or plow to be used to remove the existing sealant from the joints. The contractor used two tractor-mounted plow devices to help increase production.

b. Self-propelled concrete power saw with a water-cooled diamond or abrasive saw blade. The contractor selected to use abrasive saw blades in an effort to improve productivity. The abrasive blades had to be changed frequently because of wear. But abrasive blades do not require water; therefore, extra time to allow the water to evaporate from the joints was not required.

c. Sandblasting equipment was used to remove any residual material that might be left from the sawing operation or to remove debris that could have blown into the joints if work was delayed.

d. An air compressor equipped with water and oil traps was used with the sandblasting equipment and was also used to blow the loose sand and debris out of the joints immediately prior to sealing.

e. A vacuum sweeper was used to remove all sand and debris from the pavement surface. The sweeper helped in two areas; since debris was removed from the pavement surface it could not blow back into the joint and contaminate the joint walls and the removal of debris allowed the working areas to be opened up for use when the airport authority needed the areas.

f. The hot-poured sealing equipment or melter consisted of a double-boiler type configuration and an agitator in the kettle to prevent localized hot spots which could cause overheating of the sealant. Both types of hot-applied sealants were installed using this equipment.

g. The two-component, cold-applied sealing equipment was equipped with positive displacement pumps to deliver a one-to-one ratio of component A to component B to the mixing head. The sealant reservoirs were equipped with mechanical agitators to

prevent separation of the individual components. The contractor found it difficult to keep this equipment in proper working order.

h. The single-component, cold-applied sealing equipment consisted of a pneumatic extrusion pump, a following plate, and hoses to deliver the sealant from the packaging container into the joint.

The procedures (see appendix B) at each of the airport locations consisted of removing the existing sealant using the tractor-mounted plow. The plows used were smaller than the nominal width of the joints at each location but some chipping and damaging of the concrete in isolated areas occurred.

Once the existing joint sealant material had been removed, a concrete saw with an abrasive blade was used to reface the joints and help remove some of the remaining sealant residue from the joint wall. One problem that occurred using the abrasive blades was the rate at which the blades deteriorated. In some cases the operator would place too much pressure on the blade in the joint causing the blade to fly apart. The contractor tried to dry saw using diamond blades but only for a short time. The contractor felt that the risk of dry sawing with diamond blades far outweighed the potential benefits.

The next step in the joint preparation procedure was sandblasting. The contractor used a multiple pass technique in which one of the joint walls was sandblasted clean for the full length of a slab and then the opposite wall was sandblasted. The multiple pass technique allows the sand to directly impinge the joint face and provides better cleaning of the face. Sandblasting was followed by cleaning the joints out with compressed air to remove all sand from the joint. A vacuum sweeper was used continuously during the cleaning procedures to prevent debris from blowing out of the work area.

After the joints had been prepared and inspected, the contractor placed the backer rod material into the joint using a hand held roller device. Different size wheels and spacers could be added to the roller device to place the backer rod at the appropriate depth. The joints were then inspected and the sealant installed.

The sealants were installed using the appropriate sealing equipment at the specified temperature. The wand of the sealant equipment was installed into the bottom of the joint reservoir to allow the joints to be filled from the bottom to the top. This type of application minimizes the entrapment of air and therefore helps to reduce bubbling of the sealant.

All of the sealants were recessed in the joint approximately 1/8 to 1/4 inch below the pavement surface. The sealant was

recessed to allow for expansion of the material when the joints contracted and to prevent abrasive damage which could be caused by traffic.

Every effort was made to follow the manufacturer's recommendations concerning the sealant shape factor or depth-to-width ratio of the sealant material in the joint. In some instances, the non-uniformity of the joints prevented the exact shape factor from being used. Some of the failures at the different airport locations can probably be attributed to this factor. This is especially true of the sealant failures located on the taxiway area at Reno-Cannon International Airport.

Generally, the problems that were encountered during the sealant project were associated with construction procedures and these were usually corrected very quickly because of the partnering relationship between the contractor and the inspector. Since most of the work was conducted during the night, inspection of the joints became very critical. At times the contractor would have to reclean an area to remove sealant residue or blow sand from the joints.

LABORATORY ANALYSIS

The joint sealant materials used for this project were analyzed in the laboratory before they were installed in the field and then again after they had aged in the field approximately 6 to 7 months and 1 to 1.5 years. Three types of laboratory analysis were conducted: material specification testing, differential scanning calorimetry (DSC), and Fourier Transform Infrared Spectroscopy using Attenuated Total Internal Reflectance (FTIR-ATR).

MATERIAL SPECIFICATION TESTING.

Material specifications have been developed for various types of joint sealant materials. The specifications are used by user agencies as a means of generically specifying joint sealant materials for specific applications and to provide the user agency with a quality control tool. For example, pavements that are aircraft parking aprons and gateway areas are exposed to fuel and hydraulic fluid spillage. Therefore, a sealant that does not degrade when exposed to those chemicals is generally specified. The definition of fuel resistance is often dependent upon the user agency. Some agencies require the sealant material to meet the specification requirements of Federal Specification (FS) SS-S-1614A, FS SS-S-200E, American Society for Testing and Materials (ASTM) D 3569, or ASTM D 3581. All of these specifications have test requirements which are designed to provide an indication of the ability of the sealant to resist changes in mass and resist adhesive and/or cohesive failures after being submerged in Reference Fuel B (a mixture of 70 percent isooctane and 30 percent toluene by volume).

Some joint sealant manufacturers contend that the fuel resistance tests described in the above specifications are too severe and are not consistent with actual field conditions to which the sealant will be exposed. In contrast to submerging the sample in Reference Fuel, these manufacturers recommend exposing the top surface of the sample to the fuels and fluids that may be encountered in actual use. After exposure to the fuel or fluid, the sample is allowed to dry and then tested for the desired property. While both sides of the argument have some valid points, it is ultimately the responsibility of the user agency to determine how critical fuel resistance is in a given area and what test will be used.

For the purposes of this study, if an industry accepted material specification was not available for the sealant material, the manufacturer's recommended material specification was used. Consequently, if fuel resistance testing was not listed in the specification then it was not conducted. The one material that did not include fuel resistance testing in the recommended specification was the Dow Corning® 888SL.

The following sealants and specifications were used for this project.

a. Dow Corning® 888SL, a self-leveling, single-component silicone material. The FAA Engineering Brief 36 specification originally selected for testing this material is provided in table 1. The manufacturer material specification provided in table 2 was used for conformance testing.

b. Koch Materials Product 9012, a coal tar-based, hot-applied, jet-fuel-resistant sealant. ASTM D 3569 and FS SS-S-1614A material specifications (tables 3 and 4) were used for conformance testing. This sealant is supplied from the manufacturer in solid form.

c. Crafcro Superseal 1614A, a coal tar-based, hot-applied, jet-fuel-resistant sealant. ASTM D 3581 (table 5) and FS SS-S-1614A material specifications were used for conformance testing. This sealant is supplied in liquid form from the manufacturer.

d. Koch Materials Product 9015, a polysulfide-based, cold-applied, two-component, jet-fuel and heat-resistant sealant. FS SS-S-200E test requirements (Table 6) were used for conformance testing.

e. Koch Materials Product 9050SL, a cold-applied, single-component, polysulfide-based material. The manufacturer material specification provided in table 7 was used for conformance testing.

It is important to note that each of the material specifications contain several individual test criteria. A sealant being tested for specification conformance must meet all of the individual criteria. Failure to meet any one of the criteria is considered nonconformance. Consequently, nonconformance to the material specification would generally imply that the sealant would not be approved for use on a joint sealant project.

All of the sealant materials used for this project conformed to the appropriate material specification and the test results for each sealant are provided in tables 8 through 12. Although material specification conformance does not provide a direct indication of field performance, material specification conformance has long been considered the first step in obtaining satisfactory field performance. Additionally, if one is going to consider whether or not changes should be made to current practices, the consequences of adhering to the current practices must be documented.

Table 1. FAA Engineering Brief 36, Test Requirements as Modified for Self-Leveling Sealants.

TEST	REQUIREMENT
Self-Leveling: (Fed. Spec. SS-S-200E)	
Level plane	No flow to a variation of the surface greater than 1/8 inch
1.5 percent incline	No flow to a variation of the surface greater than 1/16 inch
Tack free time (Fed. Spec. SS-S-200E)	6 hours maximum
Durometer Hardness * (ASTM D 2240)	15 maximum
Modulus at 150 percent Elongation * (ASTM D 412 Die C)	75 psi maximum
Total Elongation (ASTM D 412 Die C)	800 percent minimum
Adhesion to Concrete (Fed. Spec. TT-S-00227E)	20 pounds minimum
Movement (ASTM C 719)	± 50 percent minimum

* Sample cured for 7 days at 77±2°F and 50±5% relative humidity.

Table 2. Material Specification Requirements for Dow Corning®
888SL.

TEST	METHOD	REQUIREMENT
As Supplied		
Appearance	CTM ¹ 0176	Smooth, homogeneous, nongrainy mixture
Extrusion Rate	MIL-S-8802	100 - 600 grams/minute
Specific Gravity	ASTM D 1475	1.29 - 1.39
Nonvolatile Content	CTM 0208	93 percent minimum
Skin-Over Time	CTM 0098	60 minutes maximum
Upon Complete Cure		
Modulus at 150% Elongation ²	ASTM D 412, Die C	13 to 30 psi
Elongation	ASTM D 412 Die C	1300 percent minimum
Adhesion to Concrete ²	ASTM D 3583 Sect. 14 Modified	550 percent minimum
Performance Movement	ASTM C 719	10 cycles +100/-50 percent, no failure
Accelerated Weathering	ASTM D 793	No defects after 5000 hours

Information supplied by Dow Corning.

¹ In most cases, Corporate Test Methods (CTMs) correspond to ASTM standard test. Copies of CTMs are available from Dow Corning upon request.

² Sample cured 21 days at 25±1°C (77±2°F) and 50±5 percent relative humidity.

Table 3. ASTM D 3569 Test Requirements.

TEST	REQUIREMENT
Application Temperature(°F)	Pouring temperature shall be the safe heating temperature as determined by the manufacturer.
Melting Time	6 hours
Penetration, 77°F (mm)	
Nonimmersed	Shall not exceed 13.0
Fuel-immersed	Shall not exceed that of the non-immersed
Flow at 158°F	Shall be no flow after 72 hours
Bond to Concrete (0°F)	
Nonimmersed	No specimen shall develop any crack, separation, or other opening in the sealing compound or between the sealing compound and the concrete blocks.
Fuel-immersed	No specimen shall develop any crack, separation, or other opening in the sealing compound or shall develop any separation between the sealant and the concrete block deeper than 1/4 inch
Water-immersed	Same as nonimmersed
Resilience:	
Unaged Recovery, percent	Minimum of 60
Aged Recovery, percent	Minimum of 60
Artificial Weathering	Shall not flow, show tackiness, the presence of an oil-like film or reversion to a mastic-like substance, form internal voids, have surface crazing, cracking, hardening, or loss of rubber-like properties, or show evidence of physical change in the surface of the material.
Tensile Adhesion	500 percent minimum elongation
Flexibility	No indication of surface crazing or cracking
Solubility (Change in weight)	Shall not exceed ±2 percent

Table 4. Federal Specification SS-S-1614A Test Requirements.

TEST	REQUIREMENT
Application Temperature(°F)	Pouring temperature shall be the safe heating temperature and shall be determined by the manufacturer.
Melting Time	3 hours
Penetration, 77°F (mm)	
Nonimmersed	Shall not exceed 13.0
Fuel-immersed	Shall not exceed 15.5
Change	Increase shall not change more than 2.5 from nonimmersed
Change in Weight, percent	Shall not exceed 2.0
Flow at 140°F (mm)	Shall not exceed 30.0
Bond to Concrete (0°F)	
Nonimmersed	Not more than 1 specimen out of 3 shall develop any crack, separation, or other opening in the sealing compound or between the sealing compound and the concrete blocks.
Fuel-immersed	None of the 3 samples shall evidence a complete cohesive failure of the material and the gross area of bare concrete exposed on the face of any 1 concrete block shall not exceed an area of 1/4 square inch.
Water-immersed	Same as nonimmersed

Table 5. ASTM D 3581 Test Requirements.

TEST	REQUIREMENT
Application Temperature(°F)	Pouring temperature shall be the safe heating temperature and shall be determined by the manufacturer.
Melting Time	90 minutes
Penetration, 77°F (mm)	
Nonimmersed	Shall not exceed 13.0
Fuel-immersed	Shall not exceed 15.5
Change	Increase shall not be more than 2.5 over nonimmersed
Solubility (Change in Weight)	Shall not exceed 2.0 percent
Flow at 140°F (mm)	Shall not exceed 30.0
Bond to Concrete (0°F)	
Nonimmersed	Not more than 1 specimen out of 3 shall develop any crack, separation, or other opening in the sealing compound or between the sealing compound and the concrete blocks.
Fuel-immersed	Not more than 1 specimen out of 3 evidence a complete cohesive failure of the material and the gross area of bare concrete exposed on the face of any 1 concrete block shall not exceed an area of 1/4 square inch.
Water-immersed	Same as nonimmersed.

Table 6. Federal Specification SS-S-200E Test Requirements.

TEST	REQUIREMENT
Accelerated Aging, sealed container, 120°F, 21 days	
Visual:	No settling, separation, or hardening that will not return to a homogeneous liquid by simple stirring, no skinning greater than 1/16 inch thick.
Self-Leveling:	
Level plane	No flow to a variation of the surface greater than 1/8 inch.
1.5 percent incline	No flow to a variation of the surface greater than 1/16 inch.
Change in Weight by Fuel Immersion, percent	Shall not exceed 2.0 of the initial weight
Change in Volume on Exposure to Elevated Temperature, 158°F, 168 hours, percent	Shall not exceed 5.0 of the initial volume
Resilience:	
Unaged	
Initial indentation, (mm) Recovery, percent	0.5 to 2.0 Minimum of 75
Aged	
Initial indentation, (mm) Recovery, percent	0.5 to 2.0 Minimum of 75
Resistance to Artificial Weathering, 140°F, 160 hrs Test panels	(a) No breakdown of cure or reversion of the sealant (b) No blistering or deformation greater than "blister size No. 2" and classed as "medium dense" in accordance with ASTM D 714

Table 6. Federal Specification SS-S-200E Test Requirements
(Continued)

TEST	REQUIREMENT
Artificial Weathering (continued)	
Volume change, percent	Shall not exceed 5.0 of initial volume
Bond to Concrete (-20°F)	
Nonimmersed	None of the specimens shall develop any surface checking, cracks, separation or other opening in the sealant. No hardness or loss of rubber-like characteristics in the sealant.
Fuel-immersed	Same as Nonimmersed
Water-immersed	Same as Nonimmersed
Flame Resistance	Shall not support combustion, flow, harden, or lose adhesive strength
Flow, cm, 5 hrs, 200°F	No cracking or dimensional change
Type M Sealant	(a) Pressurized mixing and extruding equipment shall be used (b) One to one ratio ± 5 percent by volume of Parts A and B (c) Viscosity, $75 \pm 5^\circ\text{F}$ Part A 200,000 cP max. Part B 200,000 cP max. (d) Working life to allow ample time for filling joints (e) Tack-free time 3 hrs max.
Type H Sealant	(a) N/A (b) Ratio Parts A to B supplied by the manufacturer (c) Viscosity, $75 \pm 5^\circ\text{F}$ Part A 150,000 cP max. Part B 150,000 cP max. (d) Same as Type M (e) Tack-free time 12 hrs max.

Table 7. Material Specification Requirements for Koch Materials Product 9050SL.

TEST	METHOD	REQUIREMENT
Sealant Consistency	-----	Self-Leveling
Viscosity	-----	20000 - 50000 cps
Tack-Free Time	ASTM C 679	15 - 75 minutes
Specific Gravity ¹	ASTM D 1475	1.5 - 1.56
Durometer Shore A ¹	ASTM D 2240	10 - 25
Modulus at 150%	ASTM D 412,	45 maximum
Elongation ¹	Die C	
Elongation ¹	ASTM D 412 Die C	700 percent minimum
Bond to Concrete, ²		
Nonimmersed	ASTM D 3406	Pass 3 cycles
Water-Immersed	ASTM D 3406	Pass 3 cycles
Fuel-Immersed	FS SS-S-200E	Pass 3 cycles
Tensile Adhesion ¹ 1/2" x 1/2" x 2" specimens	ASTM D 3583	400 percent minimum
Accelerated Weathering	ASTM D 793	No blisters, cracking, reversion

Information supplied by Koch Materials Company.

¹ Sample cured 21 days at 23±2°C (73±5°F) and 50±5 percent relative humidity.

² Tested at -20°F, 100% extension with a specimen size of 1/2" x 1/2" x 2".

Table 8. Specification Conformance Test Results of Koch
Materials Product 9012.

TEST	SS-S-1614 RESULTS	D-3569 RESULTS
Application Temperature (°F)	280°F	280°F
Melting Time	3 hours	6 hours
Penetration, 77°F (mm)		
Nonimmersed	8.1	9.2
Fuel-immersed	7.8	6.5
Change	-0.3	N/A
Change in Weight, percent	0.2	0.1
Flow (mm)	0.0	0.0
Bond to Concrete (0°F)		
Nonimmersed	Satisfactory	Satisfactory
Fuel-immersed	Satisfactory	Satisfactory
Water-immersed	Satisfactory	Satisfactory
Flexibility	N/A	Satisfactory
Resilience		
Unaged (%)	N/A	69
Aged (%)	N/A	70
Artificial Weathering	N/A	Satisfactory
Tensile Adhesion	N/A	750%

Table 9. Specification Conformance Test Results of Crafco
Superseal 1614A.

TEST	SS-S-1614 RESULTS	D-3581 RESULTS
Application Temperature	270°F	270°F
Melting Time	3 hours	90 minutes
Penetration, 77°F (mm)		
Nonimmersed	10.1	10.5
Fuel-immersed	9.3	10.1
Change	-0.8	-0.4
Change in Weight, percent	0.2	0.3
Flow (mm)	0.0	0.0
Bond to Concrete (0°F)		
Nonimmersed	Satisfactory	Satisfactory
Fuel-immersed	Satisfactory	Satisfactory
Water-immersed	Satisfactory	Satisfactory

Table 10. Federal Specification SS-S-200E Test Results for Koch
Materials Product 9015M.

TEST	RESULTS
Accelerated Aging, sealed container, 120°F, 21 days	
Visual:	Satisfactory
Self-Leveling:	
Level plane	Satisfactory
1.5 percent incline	Satisfactory
Change in Weight by Fuel Immersion, percent	1.4
Change in Volume on Exposure to Elevated Temperature, 158°F, 168 hours, percent	2.0
Resilience:	
Unaged	
Initial indentation, (mm)	0.7
Recovery, percent	85
Aged	
Initial indentation, (mm)	0.6
Recovery, percent	83
Resistance to Artificial Weathering, 140°F, 160 hrs Test panels	(a) Satisfactory (b) Satisfactory
Volume change, percent	1.1

Table 10. Federal Specification SS-S-200E Test Results for Koch
Materials Product 9015M (Continued).

TEST	RESULTS
Bond to Concrete (-20°F)	
Nonimmersed	Satisfactory
Fuel-immersed	Satisfactory
Water-immersed	Satisfactory
Flame Resistance	Satisfactory
Flow, cm, 5 hrs, 200°F	Satisfactory
Type M Sealant	(a) Used (b) Used (c) Part A - 70000 cP Part B - 44000 cP (d) Satisfactory (e) Satisfactory
Type H Sealant	Not Applicable

Table 11. Specification Conformance Test Results of Dow Corning® 888SL.

TEST	METHOD	RESULTS
As Supplied		
Appearance	CTM ¹ 0176	Satisfactory
Extrusion Rate	MIL-S-8802	284 grams/minute
Specific Gravity	ASTM D 1475	1.322
Nonvolatile Content	CTM 0208	94.62
Skin-Over Time	CTM 0098	7 minutes
Upon Complete Cure		
Modulus at 150% Elongation ²	ASTM D 412, Die C	16.4 psi
Elongation	ASTM D 412 Die C	1400 %
Adhesion to Concrete ²	ASTM D 3583 Sect. 14 Modified	360 %
Performance Movement	ASTM C 719	Satisfactory
Accelerated Weathering	ASTM D 793	Satisfactory

Test data supplied by Dow Corning.

¹ In most cases, Corporate Test Methods (CTMs) correspond to ASTM standard test. Copies of CTMs are available from Dow Corning upon request.

² Sample cured 21 days at 25±1°C (77±2°F) and 50±5 percent relative humidity.

Table 12. Specification Conformance Test Results of Koch
Materials Product 9050SL.

TEST	METHOD	RESULTS
Sealant Consistency	-----	Self-Leveling
Viscosity	-----	20000 cps
Tack-Free Time	ASTM C 679	45 minutes
Specific Gravity ¹	ASTM D 1475	1.54
Durometer Shore A ¹	ASTM D 2240	17
Modulus at 150% Elongation ¹	ASTM D 412, Die C	35 psi
Elongation ¹	ASTM D 412, Die C	825%
Bond to Concrete, ²		
Nonimmersed	ASTM D 3406	Satisfactory
Water-Immersed	ASTM D 3406	Satisfactory
Fuel-Immersed	FS SS-S-200E	Satisfactory
Tensile Adhesion ¹ 1/2" x 1/2" x 2" specimens	ASTM D 3583	500%
Accelerated Weathering	ASTM D 793	Satisfactory
Additional Test Data		
Resiliency	ASTM D 3583	83%
Change in Mass	ASTM D 3583	0.94%
Change in Volume	FS SS-S-200E	1.01%
Flame Resistance	FS SS-S-200E	Satisfactory

Test data supplied by Koch Materials Company.

¹ Sample cured 21 days at 23±2°C (73±5°F) and 50±5 percent relative humidity.

² Tested at -20°F, 100% extension with a specimen size of 1/2" x 1/2" x 2".

DIFFERENTIAL SCANNING CALORIMETRY (DSC).

Differential Scanning Calorimetry (DSC) is a thermoanalytical technique widely used in the polymeric field to determine material characterization properties that are beneficial in product design, specification and quality control, process optimization, and performance prediction. Some of the specific properties that can be measured using DSC include glass transition temperatures, melting points, oxidative stability, and thermal stability. To determine these properties, the DSC measures the heat flow associated with transitions in the material as a function of both time and temperature. This type of measurement provides quantitative and qualitative information about chemical and physical changes that occur in the material that involve endothermic or exothermic processes, or changes in heat capacity. The reader is referred to Wunderlich (Wunderlich 1990) for a more complete discussion on thermal analysis and DSC.

For example, figure 5 illustrates typical results that can be obtained from DSC analysis. Four regions are evident in this figure. The first region is the glass transition temperature (T_g) which is an endothermic process. Below T_g , the polymeric material undergoes a significant change in properties due to the virtual cessation of local molecular movement. In the case of a pavement joint sealant, the properties would change from being soft, flexible, and resilient above the T_g to hard, stiff, and brittle below T_g . Theoretically, this implies that when the joint begins to open during cooler temperatures, the sealant could fracture and fail. Based upon this discussion, it would appear that the user would simply select a sealant that has a T_g below the minimum expected temperature to which the sealant would be exposed. However, the T_g of various materials can be increased by the aging and weathering of the material. The T_g can also be increased if the material continues to cure or if additional cross-linking occurs. The increase in T_g could be significant enough to make the sealant become brittle at normal temperatures experienced during the winter months.

Often the T_g of polymeric materials is not as easily discernable as illustrated in figure 5, especially if the material is a mixture of constituents. Also some of the raw materials used to produce joint sealant materials, asphalt cement and coal tar for example, do not exhibit a true well-defined T_g .

The second region marked on the figure is the temperature at which crystallization (T_c) occurs in the material and it is an exothermic process. This peak will be present only in materials that exhibit some crystallinity (i.e., an ordering of the molecules or a preferred orientation of molecules that is repeated throughout the system). It was expected that most of the pavement joint sealant materials would be amorphous in nature (i.e., no

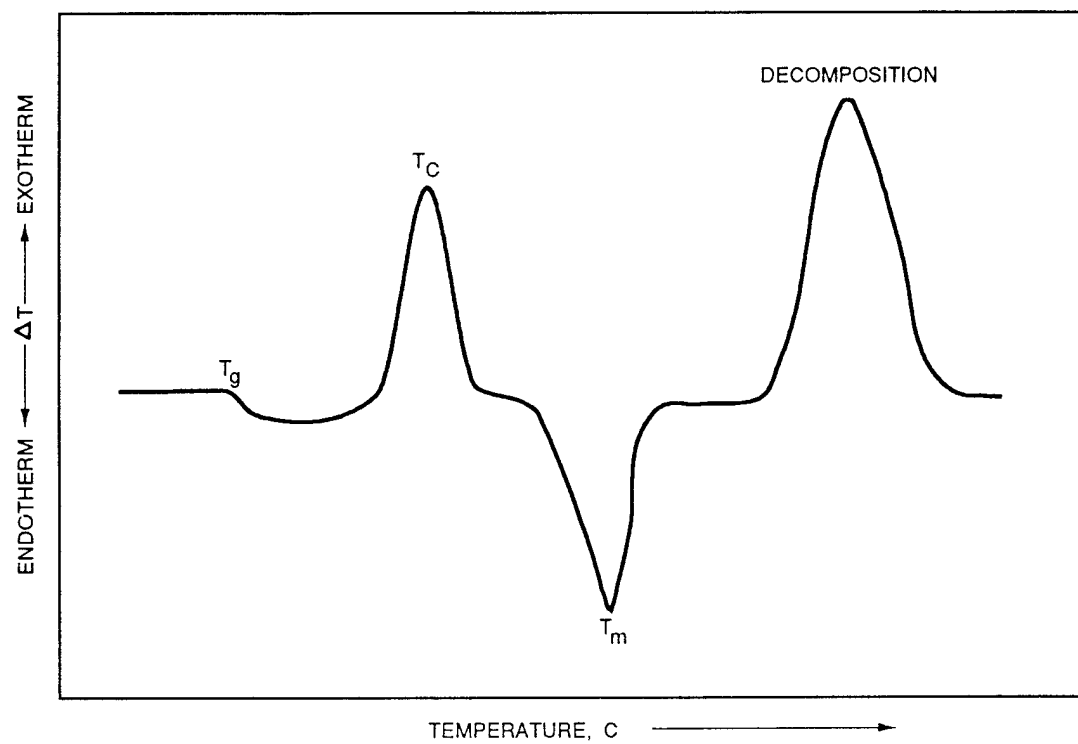


Figure 5. Typical DSC Analysis Results.

ordering or preferred molecular orientation); therefore, this peak was not expected to be present.

The third region highlighted on the thermogram is the crystalline melt temperature (T_m). The crystalline phase disappears above T_m which is accompanied by changes in the physical properties of the polymer. As the temperature of the polymer increases above T_m , the polymer becomes a viscous liquid with discontinuous changes in density, heat capacity, etc. These changes are evident on the thermogram as an endothermic peak. This peak will not be present in a material that does not exhibit some amount of crystallinity.

The definition of T_m is more complex than a simple transition from solid to liquid. Since asphalt cements and coal tars are not true polymeric materials, they do not have a melting temperature. Instead these types of materials exhibit a softening point which would not be detectable on the thermogram. If any melting peaks are evident, they would be from some type of additive in the sealant.

The last region on the thermogram in figure 5 is decomposition. This is the temperature at which the material begins to char and burn. The other regions that have been discussed are reversible, that is if the temperature is decreased below the T_m the material will revert back to a solid. If the temperature is decreased below the T_g the material becomes brittle, etc. However, if the material is exposed to temperatures above the decomposition temperature and then the temperature is reduced, the material does not regenerate.

When considering joint sealant materials, the decomposition temperature becomes important when the sealant is exposed to aircraft exhaust or the exhaust from auxiliary power units (APUs). Normally, aircraft exhaust is more of a problem with military fighter aircraft because they have an angle of thrust that impinges on the pavement more than that of most commercial aircraft. However, some APUs can increase the pavement surface temperature to approximately 204°C (400°F) for extended periods of time. Therefore, in areas where aircraft maintenance could create conditions in which the pavement temperature can become elevated, sealants that have a high decomposition temperature would be preferred.

One other region that may be exhibited by some materials is an exothermic peak indicating cross-linking in the material. On figure 5, this region would be present between the T_m and the decomposition temperature. Some of the coal tar-based materials used in this investigation undergo some cross-linking. It is expected that most of the cross-linking occurs during the heating and application of the material and therefore would not be evident

in the thermograms. The cross-linking reaction is also non-reversible.

DSC PROCEDURE AND RESULTS.

The DSC data was collected using a TA Instruments DSC 10 differential scanning calorimeter. The procedure used to conduct the tests consisted of a small sample of material, usually 2 to 6 milligrams and placing it in a hermetically sealed sample container. The sample container was then placed in the DSC and the temperature was equilibrated to -135°C (-211°F). After the sample equilibrated at -135°C , a heating ramp of $10^{\circ}\text{C}/\text{minute}$ up to a maximum temperature of 300°C (572°F) was programmed into the computer equipment controls. This temperature regime is significantly wider than the temperatures to which the sealant should be exposed and therefore any transitions that occur within normal sealant use would be included in the data.

The summarized data for the joint sealant materials is presented in table 13. The initial evaluation results were taken from samples obtained during the installation of the sealant at the specific location. Initial evaluations were not conducted on the Koch Product 9050SL from Nashville, Reno, or Selfridge because these samples did not completely cure out and were subsequently damaged during shipment to WES. Evaluation of the sealant material at Nashville could not be conducted in October or November because of weather delays and scheduling conflicts between the Metropolitan Nashville Airport Authority and WES; therefore, samples were not obtained for laboratory evaluation. All of the values presented in table 13 are the T_g for the material except for the Dow Corning® 888SL. The values listed for the Dow Corning® 888SL are for what appears to be a T_m . The T_g for the Dow Corning® 888SL should be approximately -110 to -120°C based on typical properties of silicone-base materials but the T_g was not detectable using the DSC. Overall average data for the individual sealants are provided in table 14. A limited amount of statistical analysis was conducted on the overall data. The small sample size used in the testing limits the statistical significance of the data but does allow comparisons to be made between the various types of sealants.

The DSC data indicates that the two coal tar-based sealants, Crafo Superseal 1614A and Koch Materials Product 9012, have the highest T_g and they also appear to exhibit the greatest amount of variability as illustrated by the overall standard deviation of the combined results. The variability of the coal tar-based materials was somewhat expected because most coal tar is produced as a by-product during the production of coke from bituminous coal. The process consists of heating bituminous coal to approximately 2500°F or greater. The volatile product that is removed from the process contains the crude tar. Therefore, any

Table 13. Summarized DSC T_g Data for Each Location.

Sealant	Location	Initial Evaluation (°C)	March Evaluation (°C)	October/November Evaluation (°C)
Crafco Superseal 1614A	Orlando	-23.8	*	-34.8
	Nashville	-28.1	-24.5	*
	Reno	-24.2	-15.1	-23.4
	Albuquerque	-28.3	*	*
	Selfridge	-28.8	*	-13.4
Dow Corning® 888SL**	Orlando	-42.5	-36.9	-42.8
	Nashville	-42.7	-38.7	*
	Reno	-43.0	-43.6	-42.7
	Albuquerque	-42.5	-43.8	-42.9
	Selfridge	-43.3	-44.1	-42.8
Koch Product 9012	Orlando	-28.9	-14.9	-25.5
	Nashville	-20.1	-28.4	*
	Reno	-33.7	-18.9	-10.2
	Albuquerque	-24.4	-17.6	*
	Selfridge	-31.6	-23.7	-20.0
Koch Product 9015M	Orlando	-46.5	-39.0	-49.7
	Nashville	-43.7	-43.5	*
	Reno	-43.8	-41.6	-42.7
	Albuquerque	-44.6	-43.2	-43.6
	Selfridge	-46.7	-41.7	-42.7
Koch Product 9050SL	Orlando	-58.9	-50.5	-55.2
	Nashville	*	*	*
	Reno	*	-57.1	-55.8
	Albuquerque	-59.9	-57.9	-56.8
	Selfridge	*	-56.9	-56.1

* No test data available.

**The data is for T_m instead of T_g .

Table 14. Combined Sealant DSC T_g Results.

Sealant	Initial		March Evaluation		October Evaluation		Combined Data	
	°C	SD*	°C	SD	°C	SD	°C	SD
Crafco Superseal 1614A	-25.8	3.8	-21.3	6.9	-26.5	13.7	-25.1	7.9
Dow Corning® 888SL**	-42.8	0.4	-39.9	3.5	-42.8	0.1	-41.3	2.9
Koch Product 9012	-29.4	3.5	-19.1	4.2	-20.3	7.7	-22.2	6.5
Koch Product 9015M	-45.4	1.5	-41.8	6.2	-45.3	5.6	-44.0	5.0
Koch Product 9050SL	-59.4	0.7	-55.0	3.5	-55.9	0.9	-56.0	2.7

* SD = Standard Deviation.

** Values listed for the Dow Corning material are T_m instead of T_g .

change in the properties of coal being processed, the kind of oven used, the ultimate temperature and the residence time in the oven, and the pressure used in the system all affect the physical properties of the coal tar. When the process used to produce the raw materials for the sealant formulation is variable, the physical properties of the sealant are expected to be variable and this is demonstrated through the ranges of T_g .

The Koch Materials Product 9015M has the next highest T_g and it also demonstrates some variability. This material also contains some coal tar which could explain the variability. The decrease in T_g as compared to the Crafco Superseal 1614A and Koch Materials Product 9012, may be attributed to the polysulfide material which is also a constituent.

The Koch Materials Product 9050SL has the next to lowest T_g and the Dow Corning® 888SL has potentially the lowest T_g . These two materials also appear to have the least amount of variability as indicated by the smaller standard deviations of the measured property. Therefore, if the selection of a sealant material was based only on T_g and the apparent homogeneity of the material, the single-component, cold-applied materials would be selected. The hot-applied, coal tar-based materials would be the least desirable based on this analysis. However, the T_g values as presented cannot be used as the sole means of selection because it does not

include considerations for weathering or for the potential requirements of jet fuel resistance.

No conclusive trends can be delineated from the sealant DSC analysis. Visual observation of the sealants would lead one to believe that the exposed surface was becoming weathered. However, either the DSC technique, the sampling technique, the small sample population, or the heterogeneity of the sealants prevent suspected decreases in T_g from being observed. If the sealant material had been allowed to age longer (i.e., evaluated 3 or 4 years after installation), the degree of aging may be sufficient to delineate differences using this sampling procedure.

FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR).

Fourier Transform Infrared Spectroscopy using the Attenuated Total Reflectance (FTIR-ATR) technique is a chemical analysis methodology that has been used by the polymer industry as a quality control tool and forensic analysis method. In addition, FTIR-ATR has been used on a limited basis as a forensic analysis tool for pavement joint sealants (G. Lynch et al., 1992, L. Lynch and Graham 1992, and Lewandowski et al., 1992) and as a quantitative method for determining the percentage of a modifier that has been added to an asphalt cement binder (Anderton and Lewandowski 1993).

FTIR is based upon the principle that most organic compounds absorb energy in the infrared region. When an infrared beam of radiation is passed through a sample, the covalent bonds of the different functional groups absorb energy at specific characteristic frequencies. A plot of the amount of energy absorbed by a sample versus frequency is called a spectrum. An example of a spectrum is shown in figure 6. The peaks evident in the spectrum indicate specific chemical functional groups.

The reason FTIR analysis is of interest in this investigation is that certain functional groups have been used to provide information concerning the aging of selected materials (Glover et al., 1990). It could therefore be possible to determine the "age" of a joint sealant material and thereby predict the remaining life of that material.

The ATR technique allows the spectra of solid materials to be obtained. This is accomplished by placing the joint sealant material (laboratory prepared or field obtained) on an internal reflectance element (IRE). In this investigation, a germanium (Ge) crystal was used for the IRE. The Ge crystal was selected to prevent the potential of having regions that were totally absorbing (i.e., exceeding the maximum detector response).

The sample and IRE were then placed into the FTIR sample compartment where an infrared beam of energy was passed through the IRE. The IRE causes the beam to undergo multiple internal reflections which creates an effect called the evanescent wave. The beam is then collected by the detector and is converted to the type of spectra shown in figure 6.

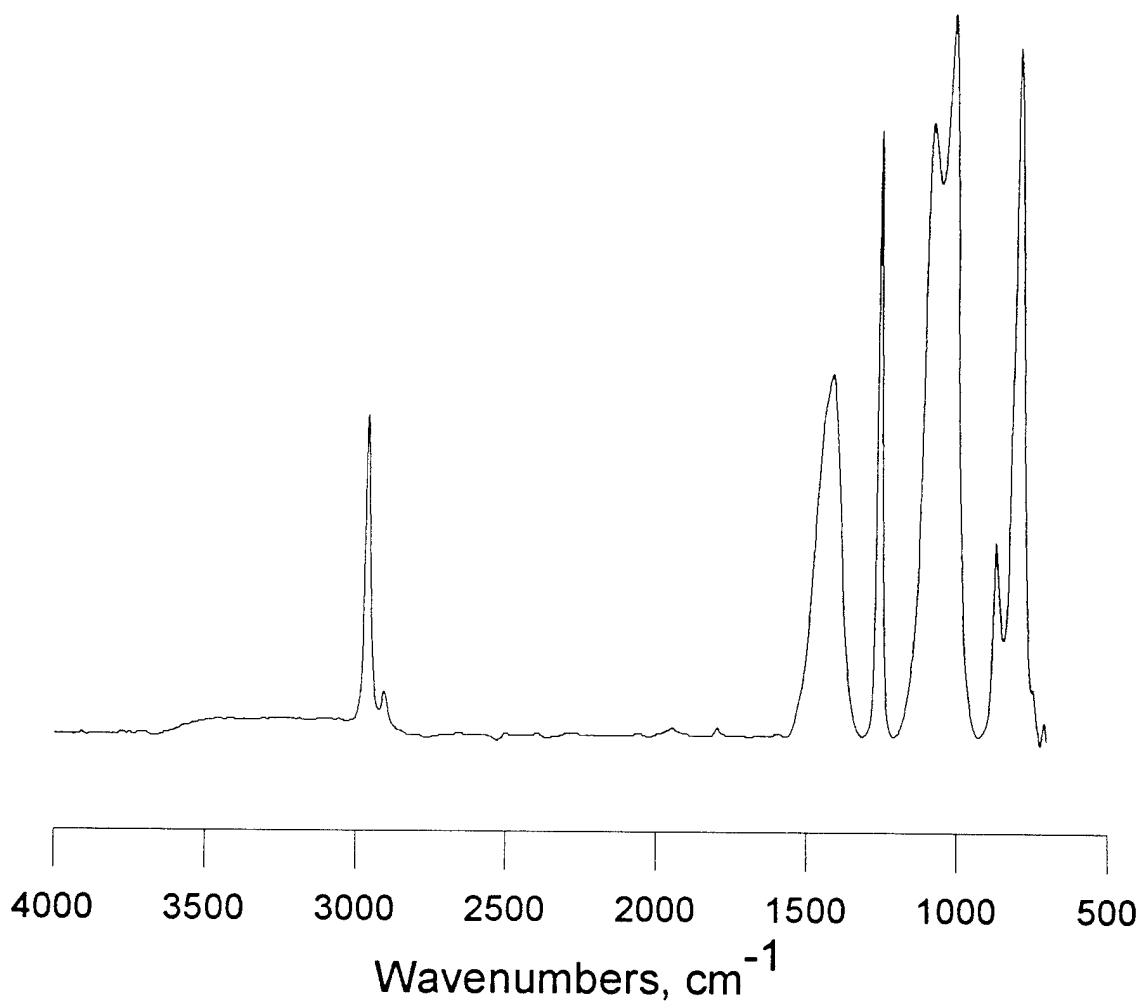


Figure 6. Example of a Fourier Transform Infrared Spectrum.

FTIR PROCEDURE AND RESULTS.

A Nicolet 510P FTIR spectrometer with a Michelson Interferometer and a Deuterium Triglyceride detector was used to collect the spectra. The experimental procedure consisted of first collecting a background signal through the IRE and then placing the joint sealant sample on the IRE and collecting the signal through the sample. The spectra was obtained by ratioing the background signal to the sample signal. The FTIR sample area was continually purged with nitrogen to remove carbon dioxide and water vapor from the system. The collection parameters used to obtain the spectra were 32 scans at a resolution of 4 cm^{-1} . The resulting spectra from the original sealant samples are presented in figures 7 through 11.

The spectra presented in these figures can provide information on the constituents used to produce the sealants. The ability to determine the age of the sealant using spectra was not successful. Perhaps the biggest obstacle to evaluating the age of the sealants using the ATR technique was the sample preparation techniques required to conduct the analysis. The ATR requires that the sample be placed in intimate contact with the IRE. If any voids are present between the IRE and the sample, the resulting spectra will not be representative of the material being analyzed. The exposed top surface of the sealant could not be placed on the IRE because it had been contaminated with dust and sand. Therefore, to obtain intimate contact between the sealant and the IRE, the sealant material had to be sliced in half for analysis. Since the aging of the sealant most likely occurs at the top exposed surface first and progresses slowly through the sealant, it is possible that this type of preparation resulted in material below the depth of aging to be analyzed. If the sealants had been allowed to age longer, the sampling technique may have been adequate.

Without information concerning the sealant formulation, it is difficult to positively identify all of the chemical constituents in the material. However, using the information provided in the Material Safety Data Sheets (MSDSs), one can verify the presence of a constituent. One problem using MSDSs in this manner is that they only list hazardous or regulated constituents. Therefore, to obtain a complete chemical make-up of the sealant, a technique such as Nuclear Magnetic Resonance (NMR) or mass spectroscopy should be coupled with FTIR. Table 15 provides the wavenumber assignments of various chemical functional groups or where peaks would be expected if the functional group is present.

Representative FTIR-ATR spectra for each of the sealants analyzed in this study are presented in figures 7 - 11. The spectra are those of actual samples collected from the field.

Table 15. Wavenumber Assignments for the Various Chemical Functional Groups

	4000	3800	3600	3400	3200	3000	2800	2600	2400	2200	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400
ALKANES	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
BRANCHED	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
ALKENES	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
vinyl	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
vinylidene	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
cis-disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
trans-disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
trisub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
ALKANES	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
monosub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
MULTI-BONDS	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Nitriles-CN	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Isonitrile-NC	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Thiocyanate-SCN	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Atrenes-C-C-C	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Isocyanates-NCO	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Isothiocyanates-NCS	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
AROMATICS	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
monosub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
ortho disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
meta disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
vicinal trisub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
para disub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
unsym. trisub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
sym. trisub.	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
CARBONYLS	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ketones - aliphatic	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Ketones - aromatic	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Esters - aliphatic	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Esters - aromatic	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Anhydrides	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Carboxylic acids	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Aldehydes	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table 15. Wavenumber Assignments for the Various Chemical Functional Groups (continued)

	4000	3800	3600	3400	3200	3000	2800	2600	2400	2200	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400
OTHER C-O & O-H																											
Carboxylate -COO-																											
Sal. Ether																											
Unsal. Ether																											
Mixed Ether																											
Epoxides																											
Alcohol - 1°																											
Alcohol - 2°																											
Alcohol - 3°																											
HALOGENS																											
Fluorine																											
Chlorine																											
Bromine																											
Iodine																											
AMIDES																											
Primary																											
Secondary																											
Tertiary																											
AMINES																											
Primary																											
Secondary																											
INORGANICS																											
Sulfur																											
Phosphorous																											
Silicon																											
Sulfates																											
Phosphates																											
Carbonates																											
Nitrates																											
Ammonium																											

Each of the samples were collected during the same period in which the joint sealants were being installed and evaluated.

In figure 7, the FTIR-ATR spectrum of the Crafco Superseal 1614A material sampled from the North Ramp at Reno International Airport is shown. The MSDS available for the 1614A material lists coal tar and rubber as major components of this joint sealant. The aromatic nature of the coal tar material is evident by the peaks near 3000 cm^{-1} (aromatic C-H stretch) 1960 cm^{-1} (overtone or combination bands), and the bands from $1600\text{--}1400\text{ cm}^{-1}$ (aromatic C-C stretch). The peaks centered around 1025 cm^{-1} arise from the in-plane bending of aliphatic hydrogens and the peaks near 750 cm^{-1} from the out-of-plane bending. There is a broad band centered at 3400 cm^{-1} indicative of intermolecular hydrogen bonding of alcohols and phenols. Due to the heterogenous nature of coal tar materials, it is impossible to assign specific peaks to either the coal tar or the rubber. This spectrum is representative of the additional samples collected from the other test areas in which this sealant was applied. Although not shown, additional spectra were obtained at approximately 6-month intervals over the course of 1 to 1.5 years after the sealants were placed into service. Examination of these spectra yielded no evidence of observable chemical changes occurring in the 1614A material with 1.5 years of aging. As with other bituminous materials, reaction with atmospheric oxygen over time results in the formation of carbonyl-containing compounds, with the appearance of bands near 1750 cm^{-1} .

The FTIR-ATR spectrum of the Koch 9012 joint sealant material is displayed in figure 8. The MSDS of this material, as with the Crafco 1614A product, lists coal tar as a major ingredient. Again, this is supported by the FTIR data which shows strong aromatic peaks at 3000 , 1960 , and 1600 cm^{-1} with aliphatic peaks near 2900 cm^{-1} . The peaks near 1025 cm^{-1} arise from the in-plane bending of aliphatic hydrogens and the peaks near 750 cm^{-1} from the out-of-plane bending. This material is similar to 1614A in that no observable chemical changes are noted from the FTIR spectra collected over a period of months.

In figure 9, the FTIR-ATR spectrum of the Koch 9015M product is shown. From the MSDS, and discussions with company representatives, this material reportedly contains a mixture of coal tars and oils and polysulfide polymer. Examination of the FTIR spectrum and comparison with the previous spectrum of the coal tar materials reveals aromatic peaks above 3000 cm^{-1} , near 1600 , and 1450 cm^{-1} with aliphatic peaks near 2900 , 1025 , and 750 cm^{-1} . However, there are several other peaks that probably arise from the presence of the polymer material in the region from $1250\text{--}1000\text{ cm}^{-1}$. These peaks are found in the range that sulfide (C-S-C) and related ether (C-O-C) linkages absorb. Analysis of the spectra collected over the course of this study indicate no readily observable chemical changes as viewed by FTIR-ATR.

In figure 10, The FTIR-ATR spectra of the Koch 9050 SL material is shown. This material is reported to contain polysulfide polymer as a major component. The FTIR-ATR spectra shows the presence of a broad absorption near 3400, typical of a alcohol or phenol-containing material. Aliphatic peaks are found centered near 2900, 1025, and 750 cm^{-1} . The peaks located between 1150-1000 cm^{-1} have previously been attributed to the polysulfide component. Additional peaks in this material are found at 1280, 1530, and 1725 cm^{-1} . The peak at 1725 cm^{-1} arises from a carbonyl-containing portion of the sealant but cannot be absolutely assigned to a particular known component. Again, no observable chemical changes occurred in this material during the 1 to 1.5 year test period.

The FTIR-ATR spectrum shown in figure 11 is that of the Dow Corning® 888SL material. This sealant is reported to be a silicone-based sealant material. Analysis of the FTIR-ATR spectra indicated that this material is primarily composed of polydimethyl-siloxane (PDMS). PDMS shows a strong absorption at 2900 cm^{-1} attributed to the methyl C-H stretch. The peaks at 1420 and 1260 cm^{-1} are due to the C-H bending modes. The strong absorption near 1000 cm^{-1} is due to the Si-O-Si bending mode. The peak centered near 750 cm^{-1} arises from the C-H bending. No changes in the spectra were observed during the 1 to 1.5 year test period.

Detailed analysis of the spectra were conducted to correlate the known chemical components of these materials with the FTIR-ATR results. No significant chemical changes in any of the materials studied here were observed during the 1 to 1.5 year test interval.

The FTIR-ATR technique is a viable method for evaluating sealants to ensure they have not been contaminated during production or delivery and to verify that multi-component materials have been mixed in the appropriate ratios. But it is not necessarily the most appropriate method to determine the aging characteristics of sealants. Methods such as FTIR microscopy and nuclear magnetic resonance (NMR) may be better suited to address these needs.

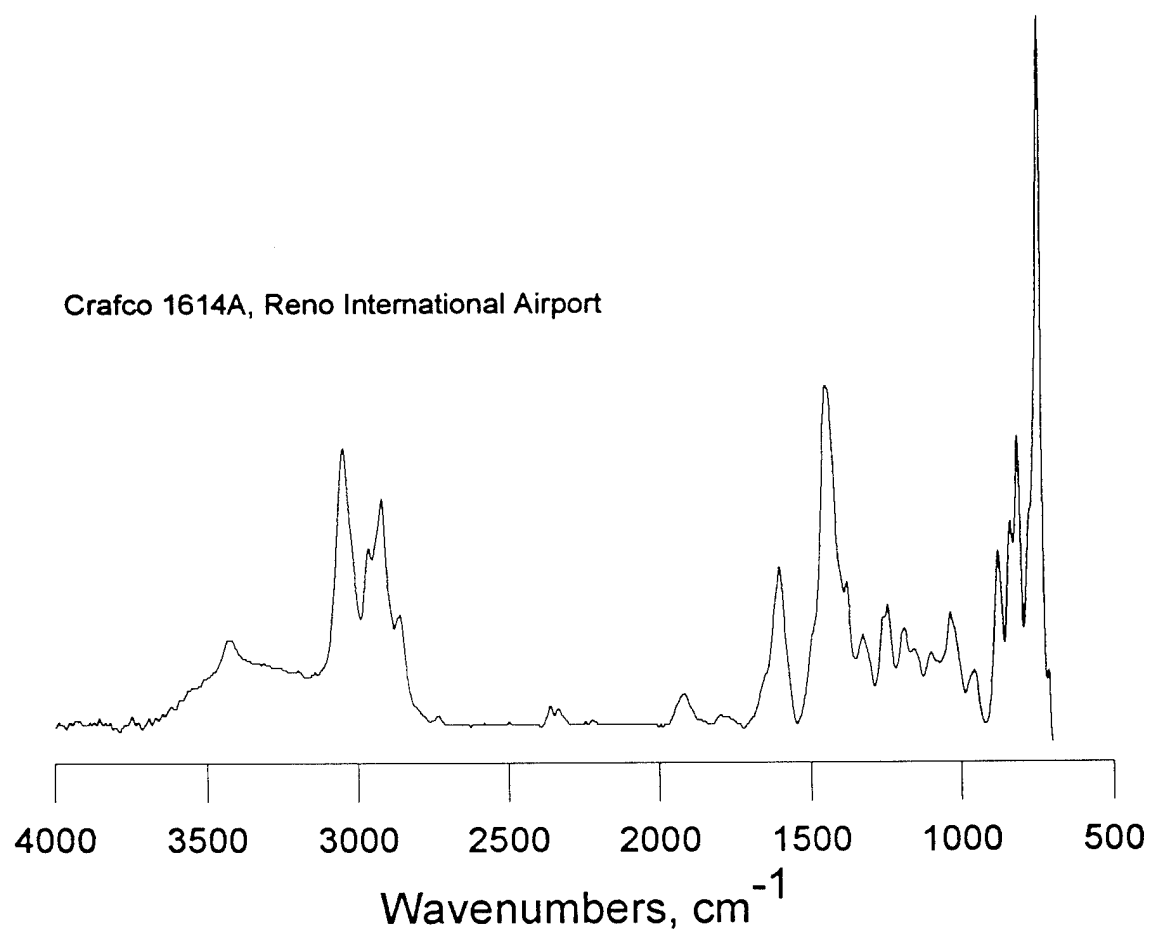


Figure 7. FTIR-ATR Spectra of Crafco Superseal 1614A.

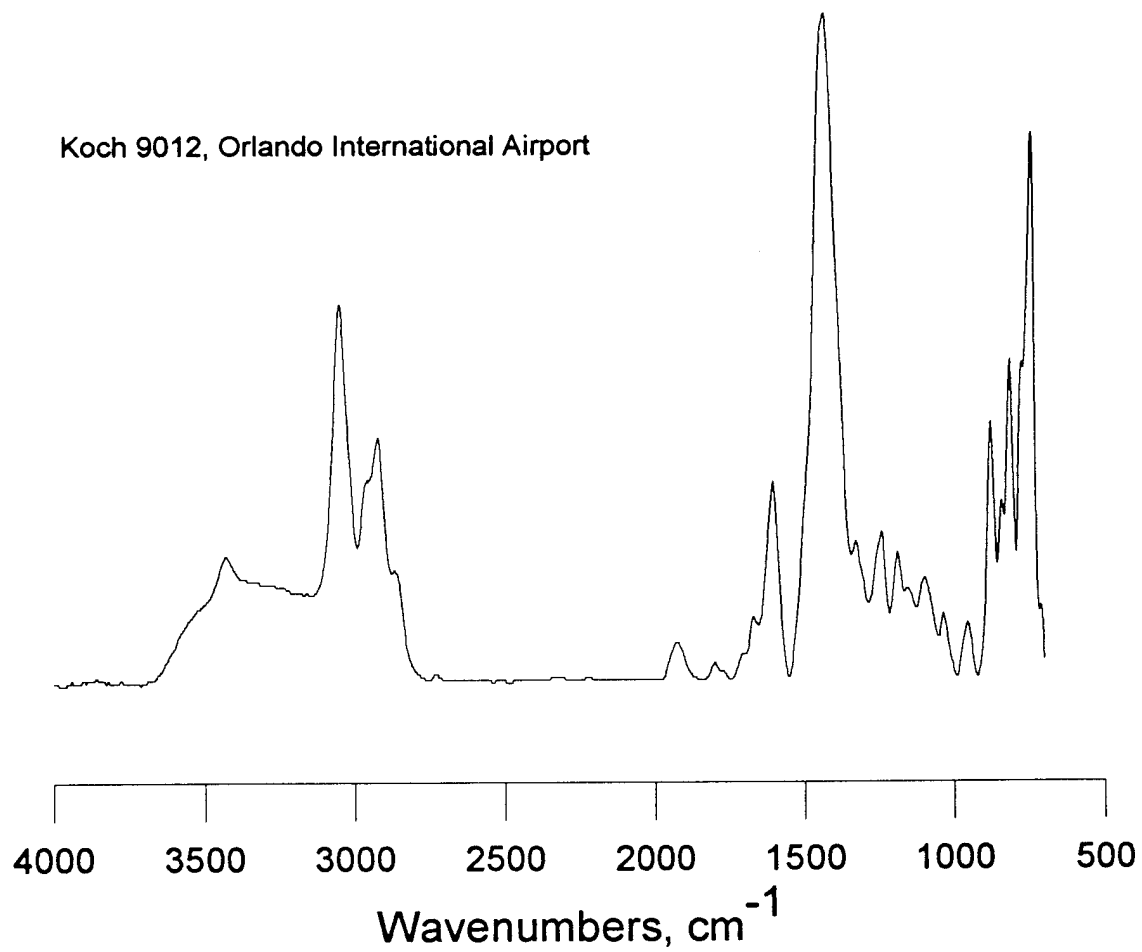


Figure 8. FTIR-ATR Spectra of Koch Materials Product 9012.

Koch 9015, Albuquerque International Airport

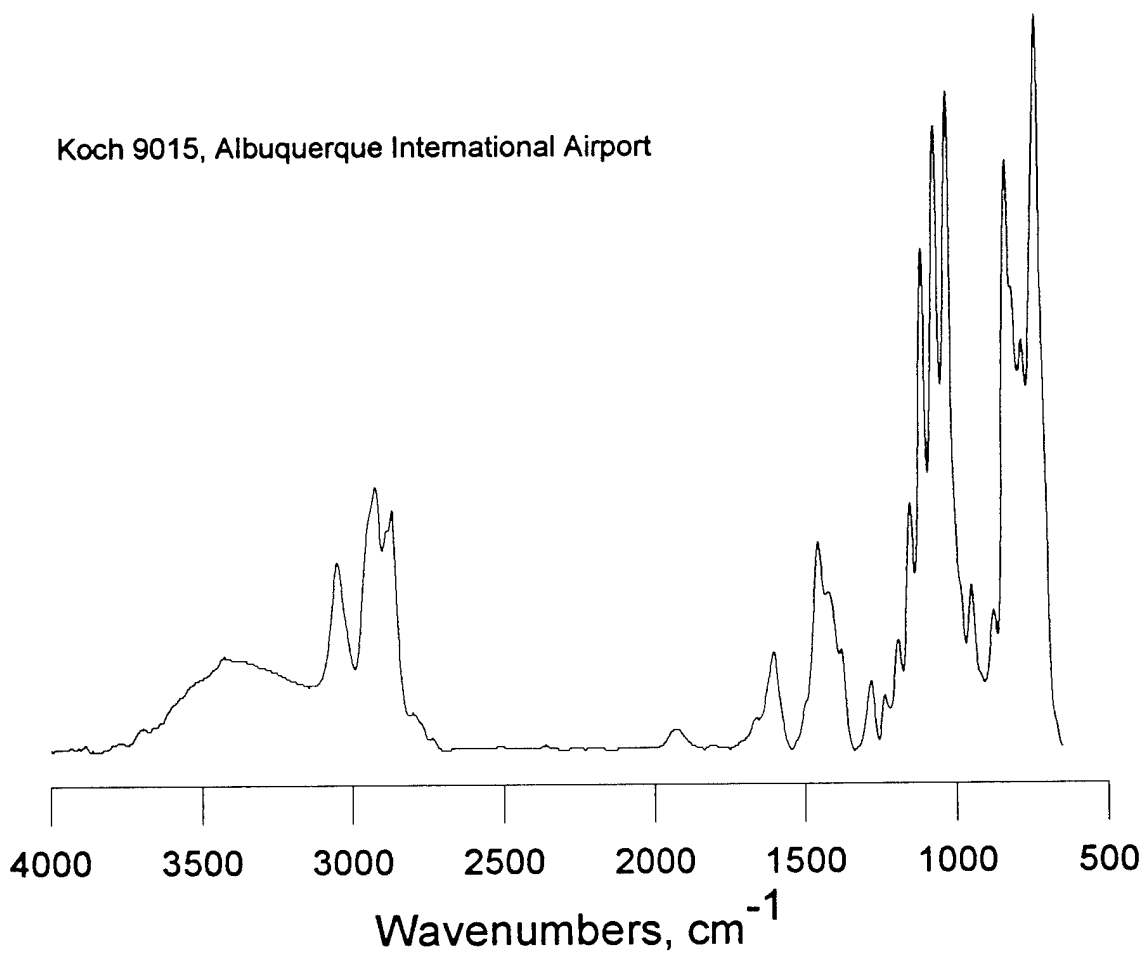


Figure 9. FTIR-ATR Spectra of Koch Materials Product 9015M.

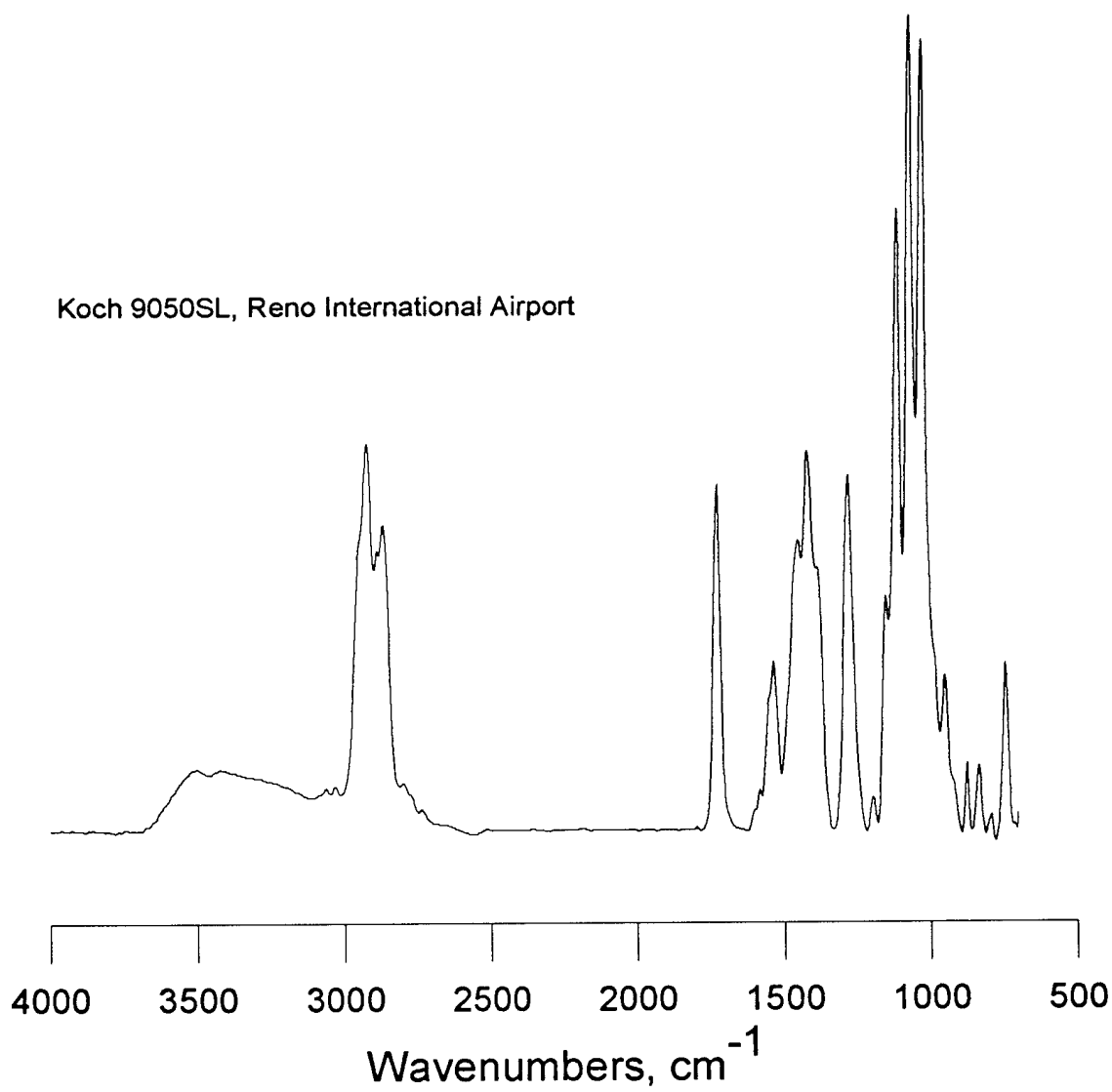


Figure 10. FTIR-ATR Spectra of Koch Materials Product 9050SL.

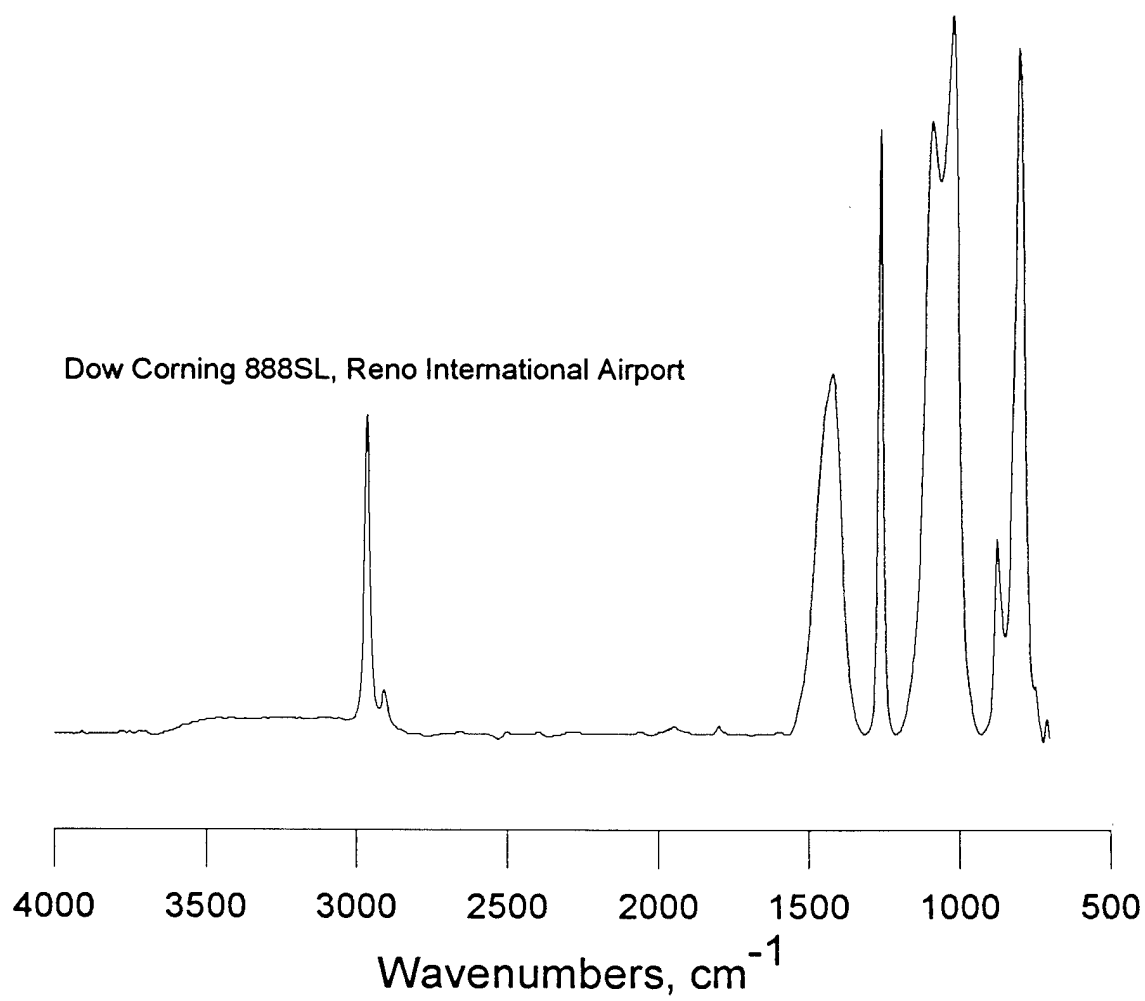


Figure 11. FTIR-ATR Spectra of Dow Corning® 888SL.

FIELD EVALUATIONS

The field evaluations were conducted approximately six months after installation and then again at approximately one year. The field evaluations consisted primarily of visual observation of the sealant condition combined with a measurement of the type of defect if any existed. The defect was then reported as a percentage of the total linear footage of that sealant section. In instances where scheduling constraints of the airport authority or when aircraft were parked in the area that was to be evaluated, a visual estimate of the percentage of defects was made.

The original field evaluation form was taken from an example used by the Ministry of Transportation, Ontario. Figure 12 is an example of the field evaluation form used during this study. This form had the amount of a defect divided into categories of "Few" (less than 11 percent), "Frequent" (between 11 and 50 percent), "Extensive" (greater than 50 percent), and "Complete" (100 percent). For the purpose of this evaluation a more precise measurement was attempted. However, when the defects had to be estimated, the percentage ranges listed above were used.

CRAFCO SUPERSEAL 1614A.

During the installation of the Crafcro Superseal 1614A some bubbling did occur in at least one test section at all five airport locations. In general, this bubbling was isolated surface bubbling, i.e., typically one to three bubbles per linear foot and the bubble diameter was typically 1/8 inch or less. The bubbling in these test sections was not of the severity that the field performance of the sealant should be affected.

The first evaluation (approximately 6 months after installation) of the Superseal 1614A sealant indicated that some adhesion failure had occurred at all five airport locations. The most common failure mode of the Superseal 1614A sealant was adhesive failure and the largest percentage of failure occurred at Reno-Cannon International Airport. It is suspected that the adhesive failures at Reno-Cannon International were caused by the relatively cool ambient temperature at the time of installation (approximately 53°F) and an application temperature that was lower than recommended by the manufacturer. The temperature of the sealant during application was lower than the recommended temperature due to delays caused by aircraft traffic combined with the small quantity of material that remained in the kettle. There was an insufficient quantity of sealant material for the project to waste this material and start over. In addition to the reduced temperature during application, the joints in the taxiway (where the largest percentage of failures occurred) did not have a uniform depth. It is assumed that the non-uniformity of the joints was a result of the initial construction of the taxiway.

FEDERAL AVIATION ADMINISTRATION
PAVEMENT JOINT SEALANT
FIELD PERFORMANCE EVALUATION

Site Location: Fairchild AFB

Sealant Location: Area Section Joint Width : Shape Factor: _____

Type of Survey: Sealant Installation Slab Size: 25' by 25'

Survey Date: _____ Sealant Material: _____

SEALANT FAILURES

Adhesion Failure		Cohesion Failure		Fuel Damage		Debris Retention	
yes	no	yes	no	yes	no	yes	no
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Few <input type="checkbox"/> <11%		Few <input type="checkbox"/> <11%		Few <input type="checkbox"/> <11%		Few <input type="checkbox"/> <11%	
Frequent <input type="checkbox"/> 11 - 50%		Frequent <input type="checkbox"/> 11 - 50%		Frequent <input type="checkbox"/> 11 - 50%		Frequent <input type="checkbox"/> 11 - 50%	
Extensive <input type="checkbox"/> >50%		Extensive <input type="checkbox"/> >50%		Extensive <input type="checkbox"/> >50%		Extensive <input type="checkbox"/> >50%	
Complete <input type="checkbox"/> 100%		Complete <input type="checkbox"/> 100%		Complete <input type="checkbox"/> 100%		Complete <input type="checkbox"/> 100%	

Remarks _____

Sealed joints in section.

Figure 12. Form Used for Field Evaluations.

The non-uniformity in the joints affected the shape factor of the sealant and could have contributed to the failures. The Crafc Superseal 1614A adhesive failures on the taxiway at Reno-Cannon International are therefore attributed to construction problems and not material deficiencies.

The Crafc Superseal 1614A sealant appeared to exhibit better field performance at the Orlando International and the Metro Nashville Airports. One section at each of these sites had some adhesive failure. In both of these instances, the adhesive failure was classified as Few (the Orlando section had less than 0.5 percent and the Nashville site had less than 10 percent). Two of the test sections at the Selfridge Air National Guard Base and three of the test sections at the Albuquerque International Airport exhibited adhesive failure. The adhesive failures at the Selfridge Air National Guard Base were rated as Few (one less than 5 percent and one less than 11 percent). Two of the adhesive failures at Albuquerque International were rated as Few (both less than 11 percent) and one was rated as Frequent (between 11 and 50 percent).

The Albuquerque International, Reno-Cannon International, and Selfridge Air National Guard Base test sections also exhibited some cohesive-type failures. These failures were rated as Few (two sections at Selfridge, one section at Reno, and one section at Albuquerque) and Frequent (one section at Reno and one section at Albuquerque).

Based upon the first evaluation, the overall performance of the Crafc Superseal 1614A versus location was from best to worst at Orlando International, Metro Nashville, Selfridge Air National Guard Base, Albuquerque International, and Reno-Cannon International. There was not a significant difference between the performance at Orlando versus Nashville or Selfridge versus Albuquerque.

The second field evaluation was conducted approximately one year after the sealants had been installed. The performance of the sealant at Orlando International did not appear to deteriorate significantly. Only two sections exhibited slight failures. They were both adhesive and both were classified as Few. Two test sections at the Selfridge Air National Guard Base had both adhesive and cohesive failures. These failures were rated as Few. One section had an adhesive failure that was rated as Few and the last section had a cohesive failure that was rated as Few.

The condition of the Crafc Superseal 1614A at the Albuquerque International Airport had deteriorated. All four tests sections had some amount of adhesive and cohesive failure. Three of the test sections had adhesive failures that were rated as Few and one had adhesive failures that was rated as Frequent. Two test sections had cohesive failures that were rated as Few and

two had cohesive failures that were rated as Excessive. The two sections with excessive cohesion failures were located on the runway.

The condition of the Crafco Superseal 1614A at the Reno-Cannon International Airport had deteriorated significantly. Three of the test sections had adhesive failures that were rated as Excessive and the last one had adhesive failures rated as Frequent. In addition, two of the test sections had cohesive failures rated as Excessive, one was rated as Frequent, and one was rated as Few.

Based upon the second evaluation, the order of performance at the different airport locations was the same as the initial evaluation, i.e., Orlando International, Selfridge Air National Guard Base, Albuquerque International, and Reno-Cannon International. The sealant at Metro Nashville was not evaluated at the one-year interval.

The limited data collected in this study seems to indicate that the Crafco Superseal 1614A performs better in wet-freeze, wet-freeze-thaw, and wet-no freeze climates as opposed to the dry-freeze and dry-freeze-thaw climates.

DOW CORNING® 888SL.

No problems were evident during the installation of the Dow Corning® 888SL material. However, it was noticed that the material appeared to cure slower in the drier climates. The contractor liked the ease of installing this single-component, cold-applied material.

The first evaluation of the Dow Corning® 888SL indicated a very small amount of adhesion failures at four of the airports. All adhesion failures were less than 0.5 percent of the total linear footage of one test section and were generally located in an area where the joint had become spalled. No adhesive failures were evident at the Albuquerque International Airport and no cohesive failures were evident. Some isolated areas had received a small amount of fuel spillage, but this did not appear to affect the overall performance of the sealant.

The overall performance of the Dow Corning sealant was good at all of the locations. The best performance was at the Albuquerque International Airport. There was no difference in the performance of the material at the Metro Nashville, the Orlando International or the Selfridge Air National Guard Base. The Dow Corning material exhibited its worst performance (as compared to the Dow Corning material at the other airports) at the Reno-Cannon International Airport.

The overall condition of the Dow Corning® 888SL had decreased slightly at the second evaluation with the exception of the material installed at the Albuquerque International Airport. The material at Albuquerque did not appear to deteriorate. No adhesive or cohesive failures were evident in the material. The greatest amount of deterioration occurred at the Selfridge Air National Guard Base and at Reno-Cannon International Airport. The rating at Selfridge changed from one test section with an adhesive failure rated as Few to three test sections with adhesive failures rated as Few. Additionally, one test section exhibited a cohesive failure that was rated as Few. The deterioration at Reno was a slight increase in the amount of adhesive failure in three of the test sections.

One concern at the beginning of the project involved the fuel resistance capabilities of silicone joint sealant materials. Some of the Dow Corning® 888SL material was exposed to a small of fuel spillage during the normal operations at the various airports. The initial results from the evaluation of these areas would indicate that in small quantities, fuel spillage does not appear to adversely affect the field performance of silicone sealants.

The Dow Corning® 888SL material performed well in all five climatic regions and was ranked as having the best or second best overall performance at the five airports. The only effect that the climate appeared to have on the silicone was the rate of cure. In the drier climates, the rate of cure seemed to be slightly retarded.

KOCH MATERIALS PRODUCT 9012.

Some isolated surface bubbling did occur during the installation of the Koch Materials Product 9012. The bubbling, when it occurred, was typically 3 to 4 per linear foot and the diameter of the bubbles was typically 1/8 inch or less. This bubbling did not appear to adversely affect the overall performance of the sealant. Adhesion failure had occurred at all five airport locations. Adhesion was the most common failure mode of the Product 9012 sealant and the largest percentage of failure (two of the test sections had approximately 50 percent adhesive failure) occurred at Reno-Cannon International Airport. The conditions during the application of the Koch Materials Product 9012 were very similar to the Crafco Superseal 1614A, i.e., the ambient temperature was in the lower 50s and the temperature of the sealant during installation decreased with successive test sections. These conditions could have contributed to the adhesive failures. The largest amount of adhesive failure occurred in the taxiway area where the joints did not have a uniform depth. The non-uniformity in the joints affected the shape factor of the sealant and could have contributed to the failures. The adhesive failures of the Koch Materials 9012 on the taxiway at Reno-Cannon

International are therefore attributed to construction problems and not material deficiencies.

The Koch Materials Product 9012 sealant appeared to exhibit better field performance at the Orlando International and the Metro Nashville Airports. One section at each of these sites had some adhesive failure. In both of these instances, the adhesive failure was classified as Few. Two of the test sections at the Selfridge Air National Guard Base and one of the test sections at the Albuquerque International Airport exhibited adhesive failure, all were rated as Few.

The Albuquerque International and Reno-Cannon International test sections also exhibited some cohesive type failures. These failures were rated as Few.

Based upon the first evaluation, the overall performance versus location rating was from best to worst at Orlando International, Metro Nashville, Selfridge Air National Guard Base, Albuquerque International, and Reno-Cannon International. There was not a significant difference between the performance at Orlando versus Nashville or Selfridge versus Albuquerque. This is basically the same results that were obtained from the Crafcu Superseal 1614A.

The second field evaluation was conducted approximately one year after the sealants had been installed. The performance of the sealant at Orlando International did not appear to deteriorate significantly. Only two sections exhibited slight failures. They were both adhesive and both were classified as Few. Two test sections at the Selfridge Air National Guard Base had adhesive failures and both of these were rated as Few. One section had a cohesive failure that was rated as Few.

The condition of the Koch Materials Product 9012 at the Albuquerque International Airport had deteriorated. All four tests sections had some amount of cohesive failure, three rated as Few and one rated as Frequent. Two of the test sections had adhesive failures that were rated as Few.

The condition of the Koch Materials Product 9012 at the Reno-Cannon International Airport had deteriorated significantly. Two of the test sections had adhesive failures that were rated as Excessive and one had an adhesive failure rated as Few. In addition, two of the test sections had cohesive failures rated as Few, one was rated as Frequent, and one was rated as Excessive.

Based upon the second evaluation, the order of performance at the different airport locations was the same as the initial evaluation, i.e., Orlando International, Selfridge Air National Guard Base, Albuquerque International, and Reno-Cannon

International. The sealant at Metro Nashville was not evaluated at the one year interval.

The limited data collected in this study seems to indicate that the Koch Product 9012 performs better in wet-freeze, wet-freeze-thaw, and wet-no freeze climates as opposed to the dry-freeze and dry-freeze-thaw climates.

KOCH MATERIALS PRODUCT 9015M.

Numerous equipment problems were encountered during the installation of the Koch Materials Product 9015M sealant. The sealing equipment used on this project was several years old and it required maintenance. The contractor stated that he had a difficult time locating the two-component equipment and that obtaining parts for repair was very difficult. The most critical problem was that occasionally one of the pumps that delivered the sealant from the sealant reservoir to the mixing head would "act-up." This caused the actual ratio of Component A to Component B to vary. It is suspected that many of the failures experienced in the Koch Materials Product 9015M potentially resulted from the equipment problems.

The first evaluation of the Koch Materials Product 9015M sealant indicated that it exhibited better field performance at the Selfridge Air National Guard Base than any of the other locations. At Selfridge, there was only one section that a failure. The failure was adhesive and it was rated as Few.

The Koch Materials Product 9015M material installed at the Metro Nashville Airport had two sections which exhibited adhesive failure. Both of these failures were rated as Few. The Koch Materials Product 9015M sealant installed at the Albuquerque International Airport had one test section that exhibited both an adhesive and a cohesive failure. Both of these failures were rated as Few, but they were more extensive than the failures experienced at Nashville. Three of the test sections at the Orlando International Airport experienced adhesive failures. All of these were rated as Few.

All of the Koch Materials Product 9015M test sections at the Reno-Cannon International Airport experienced both adhesive and cohesive failures. The two taxiway sections (area which had non-uniform joint depth) had adhesive failures that were rated Extensive. The adhesive failure in the other two sections were rated Few. The cohesive failure in the two taxiway areas were rated Frequent and the cohesive failures in the other two sections were rated Few.

Based upon the first evaluation, the overall performance versus location rating was from best to worst; Selfridge Air National Guard Base, Metro Nashville, Albuquerque International,

Orlando International, and Reno-Cannon International. There was not a significant difference between the performance at Nashville versus Albuquerque.

The second field evaluation was conducted approximately one year after the sealants had been installed. The condition of the Koch Materials Product 9015M at all of the airports had deteriorated. All four test sections at Selfridge Air National Guard Base experienced adhesive failures (three were rated as Few and one was rated as Frequent). Additionally, one of the test sections had cohesive failure rated as Few.

All of the test sections at the Albuquerque International Airport exhibited both adhesive and cohesive failure. Two of the adhesive and cohesive failures were rated as Few and two were rated as Frequent. Three of the test sections at Orlando also had adhesive failures (one rated as Few and two rated as Frequent). In addition, one of the test sections had cohesive failure rated as Few. One of the test sections could not be evaluated because aircraft maintenance was being performed in the area.

The amount of additional deterioration at Reno-Cannon was not as evident as the other locations. But because of the extent of failure at the first evaluation, this location still rated as having the poorest condition.

Based upon the second evaluation, the order of performance at the different airport locations changed slightly from the initial evaluation. The revised order was Selfridge Air National Guard Base, Orlando International, Albuquerque International, and Reno-Cannon International. The sealant at Metro Nashville was not evaluated at the one-year interval.

The limited data collected in this study seems to indicate that the Koch Product 9015M performs better in wet-freeze, wet-freeze-thaw, and wet-no freeze climates as opposed to the dry-freeze and dry-freeze-thaw climates.

KOCH MATERIALS PRODUCT 9050SL.

There were a few problems noted during the installation of the Koch Materials Product 9050SL. The biggest problem was the fact that the material was very slow in developing a tack-free surface and curing at Albuquerque International, Reno-Cannon International, and Selfridge Air National Guard Base. Some of these areas had not developed more than a thin skim on the surface after 5 days. One possible explanation for the curing problem could be that the shelf-life of the material could have expired because it had been stored at WES for approximately 1.5 years by the time the last airport was sealed. The material was used on the project even though the shelf life may have expired because the manufacturer indicated that the material still conformed to

the appropriate specification. The exact cause of the curing problem was not identified.

The contractor noted during installation that the viscosity of the Koch Materials Product 9050SL was less than that of the Dow Corning® 888SL. This created some difficulties during installation when the joints were non-uniform.

The first evaluation of the Koch Product 9050SL indicated no failures at the Orlando International or Metro Nashville Airports. Two of the test sections at Selfridge Air National Guard Base experienced adhesive failures rated as Few and one of the test sections at Albuquerque International experienced adhesive and cohesive failures, both rated as Few. Three of the test sections at Reno-Cannon International had adhesive failures, two rated as Few and one rated as Frequent. Two of these three sections also experienced cohesive failures, both rated as Few.

Based upon the results of the first evaluation, the Koch Materials Product 9050SL performed better to worst at Orlando International, Metro Nashville, Selfridge Air National Guard Base, Albuquerque International, and Reno-Cannon International. It would appear that the slow initial curing of the sealant did not adversely affect the field performance of the sealant. The majority of failures at the Reno-Cannon International Airport occurred on the taxiway where the joints varied in depth.

The second evaluation indicated that the sealant did experience some deterioration. All of the test sections at Orlando International exhibited some adhesive failure (rated as Few) and one section exhibited some cohesive failure (also rated as Few). Conversely, all of the test sections at Albuquerque International exhibited some cohesive failure (three rated as Frequent and one rated as Few). In addition, two of the sections exhibited adhesive failures rated as Few.

The largest amount of deterioration was at Selfridge Air National Guard Base. At this location two of the test sections had adhesive failures that rated as Excessive. Two other test sections had adhesive failures rated as Few.

All of the test sections at Reno-Cannon experienced adhesive and cohesive failures. Two of the sections had adhesive failures rated as Few and two rated as Frequent. All of the cohesive failures were rated as Few.

Based upon the results of the second evaluation, the order of performance at the different airport locations changed slightly from the initial evaluation. The revised order was Orlando International, Albuquerque International, Reno-Cannon International, and Selfridge Air National Guard Base. The sealant at Metro Nashville was not evaluated at the one-year interval.

The limited data collected in this study seems to indicate that the Koch Product 9050SL performs better in wet-no freeze and wet-freeze-thaw climates as opposed to the other climates in the study.

SEALANT PERFORMANCE VERSUS LOCATION.

One of the main objectives of this research was to determine if different types of joint sealant materials would perform differently depending upon the climatic region. The results provided above indicate that some materials do perform better in one climate versus another.

The first field performance or sealant condition evaluation was conducted at each of the airports approximately six months after installation of the sealants. The results from the evaluation at the Orlando International Airport which was selected to be representative of a wet-no freeze climate indicated that all of the joint sealant materials were performing satisfactorily. Only five of the 19 test sections had any failures. The failures were adhesive and the amount of failure in each of these sections was less than or equal to approximately 2 percent. No cohesive failures were evident in any of these test sections. Therefore, there was no significant difference in the condition of the sealants after the first evaluation.

After 1 to 1.5 years of field service, the number of test sections that had failures in them had increased to eleven. All of the eleven sections had adhesive failures. In addition, two of the eleven sections also had cohesive failures. The performance ranking after the one-year evaluation for the wet-no freeze climate based upon these results was

- a. the single-component, cold-applied silicone material,
- b. the two hot-applied, coal tar-based materials,
- c. the single-component, cold-applied, polysulfide material, and
- d. the two-component, cold-applied, polysulfide-based material.

One year is a short time frame to base the overall performance of a specific material in a given location and the significance of the total amount of failure between the silicone, the coal tar-based, and the single-component polysulfide material could not be quantified. The two-component polysulfide-based material did appear to be deteriorating at a higher rate than the other materials. None of the test sections had deteriorated to the point where they needed to be resealed.

Metro Nashville Airport was selected as representative of a wet-freeze-thaw climate. Only the six month evaluation was conducted at Nashville due to weather delays and scheduling conflicts between WES and Metro Nashville personnel. The evaluation indicated that there was not a significant difference in the condition of the various sealants. Five of the 20 test sections did exhibit a small amount of adhesive failure but no cohesive failures were noted. Based upon the first evaluation, the performance ranking was

- a. the single-component, cold-applied, polysulfide-based material,
- b. the single-component, cold-applied, silicone material,
- c. the two hot-applied, coal tar-based materials, and
- d. the two-component, cold-applied, polysulfide-based material.

None of the test sections at Nashville had deteriorated to the point where resealing would be required.

The Albuquerque International Airport was selected as representative of a dry-freeze-thaw climate. Eight of the 20 test sections exhibited some amount of failure at the six-month evaluation. Six of the test sections exhibited adhesive and cohesive failures and the remaining two sections exhibited only cohesive failures. The large number of cohesive failures at Albuquerque International as compared to Orlando International and Metro Nashville could be due in part to higher elevation of Albuquerque International. The higher altitude could increase the rate of aging (potentially due to the increased ultra violet (UV) radiation) thereby increasing the susceptibility of the sealants to cohesive failures. The silicone material did not appear to be affected by the increased altitude. The slower curing rate of the silicone material caused by low humidity also did not appear to affect the field performance.

After approximately one year of service, 16 of the 20 test sections exhibited cohesive failures. In addition, 14 of the 16 test sections also exhibited adhesion failures. The performance ranking of the sealants after the second evaluation was

- a. the single-component, cold-applied silicone material,
- b. one of the hot-applied, coal tar-based materials (Koch Product 9012),
- c. the single-component, cold-applied, polysulfide-based material,

d. the two-component, cold-applied, polysulfide-based material, and

e. the second hot-applied, coal tar-based material (Crafco Superseal 1614).

The significant differences in performance were that the silicone material was in much better condition than the other sealants and two of the Crafco Superseal 1614A test sections had over 50 percent cohesive failure. The two Crafco Superseal 1614A test sections needed to be resealed. The other test sections (with the exception of the silicone) will probably require resealing within the next two years.

The Reno-Cannon International Airport was selected as being representative of a dry-freeze climate. The condition of the sealants at Reno-Cannon was less satisfactory than at any of the other locations. Seventeen of the 20 test sections exhibited some type of failure at the first evaluation. The most predominate type of failure was adhesive, but there was a significant amount of cohesive failure also. By the second evaluation, 19 of the 20 test sections exhibited some type of failure. Again, the most predominate type of failure was adhesive but there was a significant amount of cohesive failures. The performance ranking based upon the second evaluation was

a. the single-component, cold-applied, silicone material,

b. the single-component, cold-applied, polysulfide-based material,

c. the two-component, cold-applied, polysulfide-based material, and

d. the two hot-applied, coal tar-based materials.

The silicone material was performing significantly better than the other materials and the single-component, cold-applied sealant was performing significantly better than the remaining materials. The remaining materials all had at least two sections that needed to be resealed with the remaining sections probably requiring resealing within the next year.

Selfridge Air National Guard Base was selected as representative of a wet-freeze climate. The overall condition of the various sealants at the first evaluation was satisfactory. Nine of the 21 test sections exhibited some minor amount of failure with the predominate mode of failure being adhesive. At the second evaluation, 17 of the 21 test sections had exhibited some type of failure. The predominate mode of failure at the second evaluation was still adhesive. The performance ranking at the second evaluation was

- a. the single-component, cold-applied silicone material,
- b. the two hot-applied, coal tar-based materials,
- c. the two-component, cold-applied polysulfide-based material, and
- d. the single-component, cold-applied polysulfide-based material.

The silicone material was performing better than the other materials and the two hot-applied materials were performing better than the remaining materials. The remaining materials, the two polysulfide based sealants, had one to two sections that needed to be resealed.

The limited data from the one-year evaluations would indicate that silicone materials should perform satisfactorily in all of the climates that were represented in this study. The hot-applied coal tar sealants exhibited satisfactory performance in the wet-no freeze, wet-freeze-thaw, and wet-freeze climates. The higher altitudes experienced at Reno-Cannon and Albuquerque International combined with the drier climate appeared to accelerate the aging of the coal tar sealants. The single-component, cold-applied polysulfide-based sealant performed satisfactorily in the wet-no freeze, and the wet-freeze-thaw climates. This material did not perform as well in the remaining climates. The two-component, cold-applied polysulfide-based material was generally ranked third or below in all of the performance evaluations. The performance ranking could have been caused by problems encountered with the application equipment. Therefore, it is suggested that the hand-mix type of this material be considered for projects until equipment problems have been corrected.

Table 16 provides a summary of the two field evaluations of the different sealants at each airport. The percentages of each type of failure listed in the table are based upon the estimates listed in the field evaluation notes. In instances where the percentage of failure from the field evaluation notes stated that the amount of failure was greater than or less than some number (i.e., >11% or <11%), that number was used to estimate the total linear feet of failure. The performance rankings that would be derived from table 16 may be slightly different from the performance rankings listed in the paragraphs above. The rankings in the above paragraphs take into account the estimated failures as greater than or less than the given number. Therefore, the rankings listed in the above paragraphs would be more indicative of the field performance ranking of the sealants.

It is evident that the sealant materials performed differently at the various locations. The same lot number of each of the materials were used at all five airports and all of the

sealants conformed to the appropriate material specification for the individual type of sealant. This confirms the fact that specification conformance does not guarantee satisfactory field performance. In addition, 100 percent inspection will not guarantee satisfactory field performance. For example, the joints in the taxiway at the Reno-Cannon International Airport were inspected before the backer rod and sealant were installed. A problem with non-uniform joint depth was identified. However, additional funds were not available to reshape the joint configuration.

The cost of joint preparation and sealant installation was the same for all of the materials. Therefore, the only difference in the cost per linear foot of the sealants was in the material cost. The two hot-applied materials cost approximately \$0.17 per foot, the two-component polysulfide material cost approximately \$0.41 per linear foot, the single-component polysulfide material cost approximately \$0.57 per linear foot, and the silicone material cost approximately \$0.67 per linear foot. These costs are based upon the materials purchased by WES and assuming a joint size of 3/4 by 3/4 inch for the hot-applied and two-component materials and a joint size of 3/4 by 1/2 inch for the two cold-applied, single-component materials. Based on these assumptions, the silicone and single component polysulfide material will have to perform 3 to 4 times longer than the hot-applied materials before they are cost effective if only the material costs are considered. However, when the cost of joint preparation is included, the silicone material must perform only 1.2 times the other materials to be cost effective. The overall cost (cost of material and joint preparation) is a more realistic manner of comparing life cycle costs. It should be noted that one study conducted by the Washington State Department of Transportation (WSDOT) (Anderson 1987) indicates that the cost of preparing joints for the application of silicone sealant materials is two to three times higher than standard joint preparation procedures. Therefore, the actual life cycle costs will vary depending upon local contracting practices.

The field evaluations indicate that a better understanding of the sealant/concrete interface is needed. Techniques for material characterization of pavement joint sealants that can provide accurate input into finite element or other modeling techniques are also required. This type of modeling could help explain the varied performance of some of the sealants and provide the needed understanding of the sealant/concrete interface.

Table 16. Field Evaluation Summary of Sealant Performance.

Sealant	Airport					
	Albuquerque		Reno		Orlando	
	6 Month ¹	1 Year	6 Month	1 Year	6 Month	1 Year
Crafco Superseal 1614A	8.1% ² A.F. ³ 5.0% C.F.	11.2% A.F. 32.4% C.F.	23.0% A.F. 8.0% C.F.	36.4% A.F. 30.4% C.F.	0.1% A.F. 0.0% C.F.	3.5% A.F. 0.0% C.F.
Koch Materials Product 9012	3.0% A.F. 5.5% C.F.	5.2% A.F. 8.6% C.F.	16.1% A.F. 2.0% C.F.	19.0% A.F. 13.0% C.F.	0.1% A.F. 0.0% C.F.	0.4% A.F. 0.0% C.F.
Dow Corning® 888SL	0.0% A.F. 0.0% C.F.	0.0% A.F. 0.0% C.F.	2.0% A.F. 0.0% C.F.	3.0% A.F. 0.0% C.F.	0.5% A.F. 0.0% C.F.	0.5% A.F. 0.0% C.F.
Koch Materials Product 9050SL	3.0% A.F. 3.0% C.F.	6.0% A.F. 12.0% C.F.	7.3% A.F. 3.4% C.F.	11.3% A.F. 4.1% C.F.	0.0% A.F. 0.0% C.F.	2.0% A.F. 0.2% C.F.
Koch Materials Product 9015	3.6% A.F. 3.6% A.F.	12.0% A.F. 12.0% A.F.	24.0% A.F. 8.2% C.F.	24.3% A.F. 8.2% C.F.	2.2% A.F. 0.0% C.F.	15.0% A.F. 2.0% C.F.

¹ Approximate age of sealant at the time of evaluation.

² The numbers provided in this chart are estimates of the total failure associated with the sealant materials at each location. Since some of the estimates provided in the field evaluations were listed as greater than or less than some number, these estimates should only be used for general comparisons.

³ A.F. is adhesive failure, C.F. is cohesive failure.

Table 16. Field Evaluation Summary of Sealant Performance (Continued).

Sealant	Airport			
	Nashville		Selfridge	
	6 Month	1 Year	6 Month	1 Year
Crafco Super-seal 1614A	0.2% A.F. 0.0% C.F.	N/A ⁴	4.4% A.F. 4.6% C.F.	6.7% A.F. 5.9% C.F.
Koch Materials Product 9012	0.2% A.F. 0.0% C.F.	N/A	3.0% A.F. 0.0% C.F.	3.0% A.F. 2.7% C.F.
Dow Corning® 888SL	0.1% A.F. 0.0% C.F.	N/A	0.2% A.F. 0.0% C.F.	1.0% A.F. 0.3% C.F.
Koch Materials Product 9050SL	0.0% A.F. 0.0% C.F.	N/A	3.0% A.F. 0.0% C.F.	24.8% A.F. 0.0% C.F.
Koch Materials Product 9015	0.1% A.F. 0.0% A.F.	N/A	0.2% A.F. 0.0% C.F.	13.0% A.F. 3.7% C.F.

⁴ Data not available.

CONCLUSIONS

Previous research conducted by NCEL and WES identified three potential problem areas that can cause pavement joint sealant failures. The three areas were inadequate materials, poor construction practices, and improper design/inspection. Additionally, sealant performance versus climate was also investigated. The conclusions of this investigation are

a. Conformance of the joint sealant material to the appropriate material specification does not signify satisfactory field performance.

b. Total inspection or 100 percent inspection will not guarantee satisfactory field performance if funding is not available to correct for changes in site conditions. However, total inspection will ensure the joints are properly prepared and/or delineate areas where sealant failure will more likely occur. This type of information is critical in forensic investigations if a sealant does fail.

c. The joint preparation procedures provided in FAA Item P-605 are adequate to obtain satisfactory field performance from a pavement joint sealant. The procedures listed in FAA Item P-605 are similar to the guidance provided by joint sealant manufacturers in the sealant informational literature.

d. The Differential Scanning Calorimeter (DSC) and Fourier Transform Infrared Spectroscopy using Attenuated Total Internal Reflectance (FTIR-ATR) can provide an indication of the physical and chemical properties of a pavement joint sealant. However, additional consideration must be given to sample preparation and sample population, etc., before quantitative information can be obtained.

e. Different joint sealant materials do perform differently in different climates. However, the silicone sealant performed satisfactorily in all of the climatic regions included in the investigation. The hot-applied, coal tar-based sealants performed satisfactorily in the wet-no freeze, wet-freeze-thaw, and wet-freeze climates.

f. The joint preparation and sealant installation costs were the same for all of the materials used in this project. Therefore, material costs were the only difference in the overall installation cost. Based on the cost of the materials purchased and stored by WES, the silicone material must perform approximately 1.2 times longer than the other sealants for them to be economically feasible. At some of the airport locations, it appears that the silicone will last at least 3 times longer.

RECOMMENDATIONS

The following research recommendations are made based upon the conclusions of this investigation:

a. Develop material specification requirements that are more closely related to actual field performance. The focus of the specifications could be on improved material characterization techniques. One potential material characterization technique would be dynamic shear rheology (DSR). DSR could be used to obtain modulus versus loading and modulus versus temperature in an oscillatory or stress relaxation mode.

b. Develop finite element models that would help provide a better understanding of the sealant behavior throughout its service life. There was 100 percent inspection on this project and the inspectors were knowledgeable concerning joint sealing projects and were diligent in inspecting the joints. However, there were still some unexplained failures. Finite element modeling or some other modeling technique could help evaluate some of these failures.

c. Continue to explore chemical analysis methods to be used as quality control and forensic tools. The FTIR-ATR sampling technique used during this project was somewhat limited for evaluating the aging process of sealants. Other techniques such as nuclear magnetic resonance or FTIR microscopy should be evaluated.

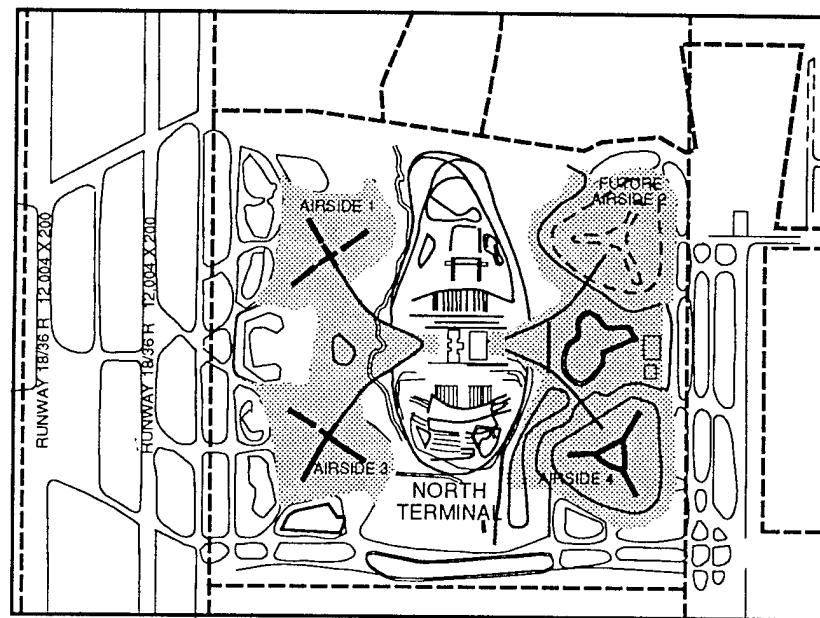
d. Continue to monitor the field performance of the sealants installed during this project annually. The evaluation period used in this project was very short. A more accurate idea of the sealant performance versus climate and the life cycle costs of the materials associated with that performance could be obtained if all of the materials were evaluated to failure.

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APPENDIX A
TEST SITES AT EACH AIRPORT



ORLANDO INTERNATIONAL AIRPORT

Figure A-1. Area Sealed at Orlando International Airport.

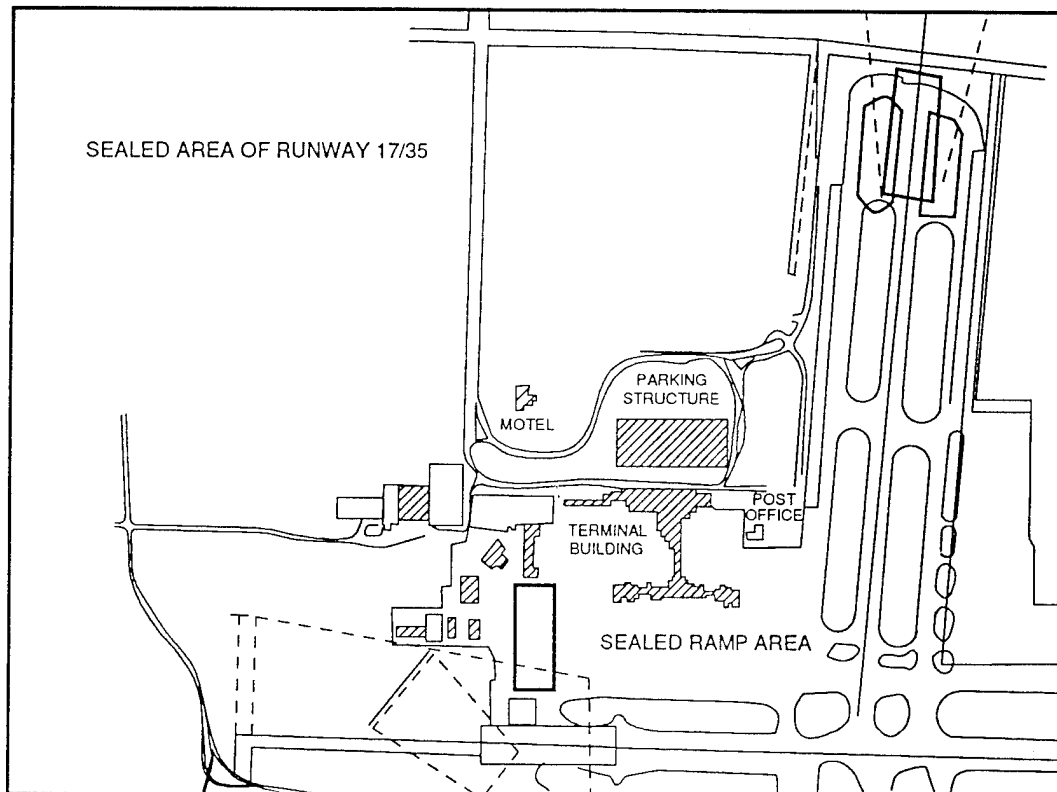


Figure A-2. Area Sealed at Albuquerque International Airport.

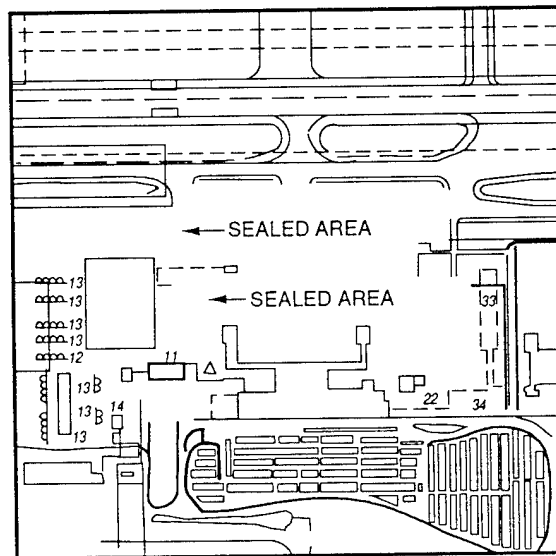


Figure A-4. Area Sealed at Reno-Cannon International Airport.

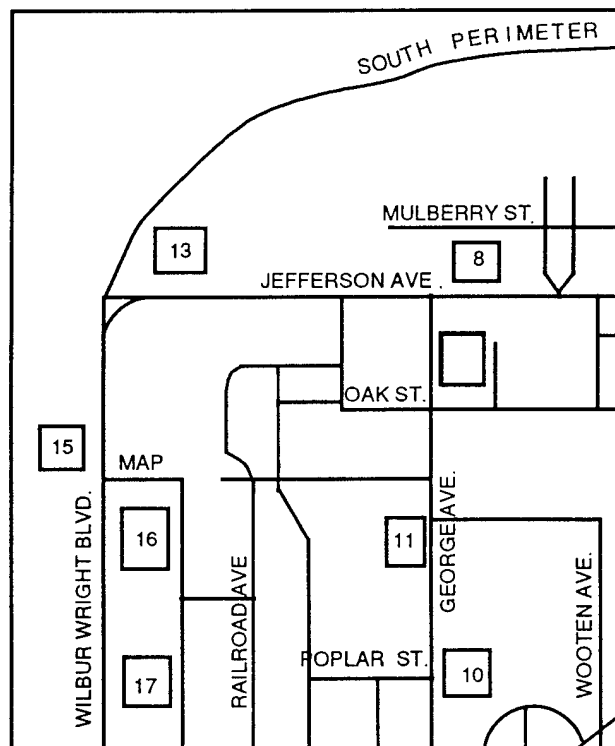


Figure A-5. Fuel Storage Area Sealed at
Selfridge Air National Guard Base

APPENDIX B

PROJECT SPECIFICATIONS

The following is an extract of Section 3 of the contract specification used for the joint sealing project.

SECTION 3

FIELD MOLDED SEALANTS FOR RESEALING JOINTS IN RIGID PAVEMENTS

PART 1 GENERAL

1.1 SUBMITTALS

The following should be submitted in accordance with Section SUBMITTALS:

Construction Equipment List

List of proposed equipment to be used in performance of construction work including descriptive data shall be submitted 7 days prior to use on the project.

Manufacturer's Descriptive Data of Backup Material

Manufacturer's descriptive data of the backup material which shows that the material meets the specification shall be submitted prior to the beginning of work. No material will be allowed to be used until it has been approved.

1.2 EQUIPMENT

Machines, tools, and equipment used in the performance of the work required by this section shall be approved before the work is started and shall be maintained in satisfactory condition at all times. The contractor shall use the same equipment and operators at each location.

1.2.1 Joint Cleaning Equipment

1.2.1.1 Tractor-Mounted Routing Tool

The routing tool used for removing old sealant from the joints shall be of such shape and dimensions and so mounted on the tractor that it will not damage the sides of the joints. The tool shall be designed so that it can be adjusted to remove the old material to varying depths as required. The use of V-shaped tools or rotary impact routing devices will not be permitted.

1.2.1.2 Concrete Saw

A self-propelled power saw with water-cooled diamond or abrasive saw blades shall be provided for cleaning sawed joints where surface films of old sealants cannot be readily removed by sandblasting.

1.2.1.3 Sandblasting Equipment

Sandblasting equipment shall include an air compressor, hose, and long-wearing venturi-type nozzle of proper size, shape and opening. The maximum nozzle opening should not exceed 1/2 in. The air compressor shall be portable and shall be capable of furnishings not less than 90 psi at the nozzle while in use. Compressor capability under job conditions must be demonstrated before approval. The compressor shall be equipped with traps that will maintain the compressed air free of oil and water. The nozzle shall be an adjustable guide that will hold the nozzle aligned with the joint approximately 1 in. above the pavement surface. The height, angle of inclination, and the size of the nozzle shall be adjusted as necessary to secure satisfactory results.

1.2.1.4 Hand Tools

Hand tools may be used, when approved, for removing defective sealants from a joint and repairing or cleaning the joint faces.

1.2.1.5 Vacuum Sweeper

A vacuum sweeper shall be required to remove all sand after sandblasting.

1.2.2 Sealing Equipment

1.2.2.1 Hot-Poured Sealing Equipment

The unit applicators used for heating and installing hot-poured joint sealant materials shall be mobile and shall be equipped with a double-boiler, agitator-type kettle with an oil medium in the outer space for heat transfer; a direct-connected pressure-type extruding device with a nozzle shaped for inserting in the joint to be filled; positive temperature devices for controlling the temperature of the transfer oil and sealant; and a recording type thermometer for indicating the temperature of the sealant. The applicator unit shall be so designed that the sealant will circulate through the delivery hose and return to the inner kettle when not in use.

1.2.2.2 Two Component Cold-Applied Sealing Equipment

The equipment used for proportioning, mixing, and installing two component cold-applied joint sealants shall be designed to deliver two semifluid components through hoses to a portable mixer at a preset ratio of 1 to 1 by volume using pumps with an accuracy of plus or minus 5 percent for the quantity of each component. The reservoir for each component shall be equipped with mechanical agitation devices that will maintain the components in a uniform condition without entrapping air. Provisions shall be incorporated to permit thermostatically controlled indirect heating of the components, when required. However, immediately prior to proportioning and mixing, the temperature of either component shall not exceed 90 degrees F. Screens shall be provided near the top of each reservoir to remove any foreign particles or partially polymerized material that could clog fluid lines or otherwise cause misproportioning or improper mixing of the two components. The equipment shall be capable of thoroughly mixing the two components through a range of application rates of 10 to 60 gal per hour and through a range of application pressure from 50 to 1,500 psi as required by material, climatic, or operating conditions. The mixer shall be designed for the easy removal of the supply lines for cleaning and proportioning of the components. The mixing heat shall accommodate nozzles of different types and sizes as may be required by various operations. The dimensions of the nozzle shall be such that the nozzle tip will extend into the joint to allow sealing from the bottom of the joint to the top. The initially approved equipment shall be maintained in good working condition, serviced in accordance with the supplier's instructions, and shall not be altered in any way without obtaining prior approval.

1.3 BARRICADES, WARNING SIGNS, AND HAZARD MARKINGS

1.3.1 Hazard Markings

The contractor shall furnish, erect, and maintain all barricades, warning signs, and markings for hazards necessary to protect the public and the work. When used during the periods of darkness, such barricades, warning signs, and hazard markings shall be suitably illuminated. Open-flame type lighting is prohibited on the air operations areas of airports. These markings shall be erected prior to commencing work which requires such erection. All

barricades, sand, and loose debris shall be removed at the end of each work period to facilitate airport traffic.

1.3.2 Temporary Markings

When the work requires closing an Air Operations Area of the airport or portion of such area, the contractor shall furnish, erect, and maintain temporary markings and associated lighting conforming to the requirements of the current edition FAA Advisory Circular 150/5340-1, Marking of Paved Areas on Airports.

1.3.3 Stock Pile and Equipment Storage Markings

The contractor shall furnish, erect, and maintain markings and associated lighting of temporary stock piles and his parked construction equipment that may be hazardous to the operation of emergency fire-rescue or maintenance vehicles on the airport in reasonable conformance to FAA Advisory Circular 150/5370-2, Safety on Airports During Construction Activity.

1.3.4 Vehicle Markings

The contractor shall identify each motorized vehicle or piece of construction equipment in reasonable conformance to FAA Advisory Circular 150/5370-2.

1.4 DELIVERY AND STORAGE

Materials delivered to the jobsite shall be inspected for defects, unloaded, and stored with a minimum of handling to avoid damage. Sealants will be delivered to the jobsite by the Government. A space will be provided at each airport for equipment and material storage.

1.5 ENVIRONMENTAL CONDITIONS

The ambient air temperature and the pavement temperature within the joint wall shall be a minimum of 50 degrees F and rising at the time of application of the materials. Sealant shall be applied if moisture is observed in the joint.

PART 2 PRODUCTS

2.1 SEALANTS

Sealants will be supplied by the Government in 5 gal containers. The five sealants to be applied by the contractor shall be:

- Sealant #1 Koch Product 9015
- Sealant #2 Koch Product 9012
- Sealant #3 Crafco Superseal 1614
- Sealant #4 Dow 888 SL
- Sealant #5 Koch Product 9050 SL

2.2 BACKUP MATERIALS

Backup materials shall be supplied by the contractor. The backup material shall be a compressible, nonshrinking, nonstaining, nonabsorptive material and shall be nonreactive with the joint sealant. The material shall have a melting point at least 5 degrees F greater than the pouring temperature of the sealant being used. The backup material shall be 25 plus or minus 5 percent larger in diameter than the nominal width of the crack.

PART 3 EXECUTION

3.1 PREPARATION OF JOINTS

Before the installation of the sealant, the joint shall be thoroughly cleaned to remove all old sealant from the sides and upper edges of the joint space to be sealed.

3.1.1 Existing Sealant Removal

The in-place sealant shall be cut loose from both joint faces and to the depth required to provide the required shape factor recommended for the sealant to be applied, using the tractor-mounted routing equipment and concrete saw as specified in paragraph EQUIPMENT. Depth shall be sufficient to accommodate backup material that is required to maintain the depth of new sealant to be installed. Prior to further cleaning operations, all loose old sealant remaining in the joint opening shall be removed by blowing with compressed air. Chipping, spalling, or otherwise damaging the concrete will not be allowed.

3.1.2 Sandblasting

The entire concrete joint faces and the pavement surfaces extending a minimum of 1/2 in. from the joint edges shall be sandblasted clean. A multiple-pass technique shall be used until the surfaces are free of dust, dirt, filler, old sealant residue, or any foreign debris that might prevent the bonding of the sealant to the concrete. After final cleaning and immediately prior to sealing, the joints shall be blown out with compressed air and left completely free of debris and water.

3.1.3 Backup Material

The lower portion of the joint opening shall be sealed off using a backup material to prevent the entrance of the sealant below the specified depth. Care shall be taken to insure that the backup material is placed at the specified depth and is not stretched or twisted during installation.

3.2 PREPARATION OF SEALANTS

3.2.1 Hot-Poured Sealants

Koch Product 9012 and Crafcro Superseal 1614 shall not be heated in excess of the safe heating temperature recommended by the manufacturer as shown on the sealant containers. Sealant that has been overheated or subjected to application temperatures for over 4 hrs or that has remained in the applicator at the end of the day's operation shall be withdrawn and wasted.

3.2.2 Two Component Cold-Applied Type M Sealant

Koch Product 9015 sealant components and containers shall be inspected prior to use. Any materials that contain water, hard caking of any separated constituents, nonreversible jell, or materials that are otherwise unsatisfactory shall be rejected. Settlement of constituents in a soft mass that can be readily and uniformly remixed in the field with simple tools shall not be cause for rejection. Prior to transfer of the components from the shipping containers to the appropriate reservoir of the application equipment, the materials shall be thoroughly mixed to insure homogeneity of the components and incorporation of all constituents at the time of transfer. When necessary for remixing prior to transfer to the application equipment reservoirs, the components shall be warmed to a temperature not to exceed 90 degrees F by placing the components in heated storage or by other approved

methods but in no case shall the components be heated by direct flame, or in a single walled kettle, or a kettle without an oil bath.

3.2.3 Single Component Cold-Applied Sealants

Dow 888 SL and Koch Product 9050 SL sealant and containers shall be inspected prior to use. Any materials that contain water, hard caking of any separated constituents, nonreversible jell, or materials that are otherwise unsatisfactory shall be rejected. Settlement of constituents in a soft mass that can be readily and uniformly remixed in the field with simple tools shall not be cause for rejection.

3.3 INSTALLATION OF SEALANT

3.3.1 Time of application

Joints shall be sealed immediately following final cleaning of the joint walls and following the placement of the separating or backup material. Open joints that cannot be sealed under the conditions specified, or when rain interrupts sealing operations shall be recleaned and allowed to dry prior to installing the sealant.

3.3.2 Sealing Joints

Immediately preceding, but not more than 50 ft ahead of the joint sealing operations, a final cleaning with compressed air shall be performed. The shape factor recommended by the sealant manufacturer shall be maintained. This shape factor shall be defined as:

$S-D/W$

S = Shape factor

D = Depth of sealant

W = Width of sealant

The depth shall be adjusted to meet the manufacturer's recommendations. It shall not exceed 1/2 in. for cold-applied single component sealants and shall not exceed 3/4 in. for two component and hot-applied sealants. The joints shall be filled from the bottom up to 1/2 in. plus or minus 1/16 in. below the pavement surface. Excess or spilled sealant shall be removed from the pavement by applied methods and shall be discarded. The sealant shall be installed in such a manner as to prevent the formation of voids and entrapped air. In no case shall gravity methods or pouring pots be used to install the sealant materials. Traffic shall not be permitted over newly sealed pavement until authorized by the Contracting Officer. Joints shall be checked frequently to insure that the newly installed sealant is cured to a tack-free condition within the time specified.

3.4 CLEAN-UP

Upon completion of the project, all unused materials shall be removed from the site and the pavement shall be left in a clean condition. All waste and debris shall be removed from airport property and disposed of by the contractor at no additional cost to the Government.

3.5 QUALITY CONTROL PROVISIONS

3.5.1 Joint Cleaning

Quality control provisions shall be provided during the joint cleaning process to correct improper equipment and cleaning techniques that damage the concrete pavement in any manner. Any concrete pavement that is damaged during joint

preparation shall be repaired by the contractor at no additional cost to the Government. Cleaned joints shall be approved prior to installation of the separating or backup material and joint sealant.

3.5.2 Joint Sealant Application Equipment

The application equipment shall be inspected to assure conformance to temperature requirements, proper proportioning and mixing of two-component sealant, and proper installation. Evidences of bubbling, improper installation, failure to cure or set shall be cause to suspend operations until causes of the deficiencies are determined and corrected.

3.5.3 Joint Sealant

The joint sealant shall be inspected for proper rate of cure and set, bonding to the joint wall, cohesive separation within the sealant, reversion to liquid, entrapped air, and voids. Sealants exhibiting deficiencies caused by improper application at any time prior to the final acceptance of the project shall be removed from the joint, wasted, and replaced as specified herein at no additional cost to the Government.

APPENDIX C
SUMMARY OF FIELD EVALUATIONS

Table C-1. Sealant Installation Summary For Orlando International Airport Gateway Area.

Sealant	Gate Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	G-2	6/05/92	527	Sealant was poured early in the morning, ambient temperature was approximately 72°F. Some isolated bubbling of the sealant was observed during installation. The width of the joints at this gate ranged from 3/8 to 5/8 inch.
Koch Product 9012	G-3	6/15/92	518	Sealant was poured early in the morning, ambient temperature was approximately 72°F. Some isolated bubbling of the sealant was observed during installation. The width of the joints in this gate ranged from 1/2 to 5/8 inch.
Koch Product 9015M	G-4	6/17/92	589	Sealant was poured early in the morning, ambient temperature was approximately 76°F. Contractor had some difficulty with application equipment, but this was corrected before installing the sealant. All joints in this area were approximately 1/2 inch wide.

Table C-1. Sealant Installation Summary For Orlando International Airport Gateway Area
(Continued).

Sealant	Gate Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9050 SL*	G-5	6/01/92	601	Most of sealant was poured early in the morning, ambient temperature was approximately 75°F. The remainder of the sealant was poured during the evening and the ambient temperature was approximately 78°F. Some bubbling was observed in the sealant during the first 10 to 15 feet of installation. It was expected that the bubbling was caused by air trapped in the equipment. The bubbling created depressions in the sealant that subsequently were refilled. The joints in this area were approximately 3/8 to 1 inch wide.
Koch Product 9015M	G-6	6/17/92	517	Same notes as listed for Gate G-4. The joints in this area were approximately 1/2 inch wide.
Dow Corning 888SL*	G-7	6/02/92	517	Sealant was poured early in the morning, ambient temperature was approximately 73°F. No problems were observed during installation. The joints in this area were 1/2 to 5/8 inch wide.

* Only one Gateway area was sealed using this material. Aircraft traffic prevented access to the area.

Table C-1. Sealant Installation Summary For Orlando International Airport Gateway Area
(Continued).

Sealant	Gate Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	G-8	6/05/92	517	Sealant was poured early in the morning, ambient temperature was approximately 72°F. Some isolated bubbling was observed during installation. The joints in this area were approximately 1/2 inch wide
Koch Product 9012	G-9	6/15/92	517	Sealant was poured early in the morning, ambient temperature was approximately 72°F. Some isolated bubbling of the sealant was observed during installation. The width of the joints in this area ranged from 1/2 to 1 inch.

Table C-2. Sealant Installation Summary For Orlando International Airport Taxiway Area.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	1	6/02/92	467	Sealant was poured early in the morning, ambient temperature was approximately 73°F. No problems were observed during installation. The joints in this area were 1/2 to 5/8 inch wide with majority of joints being 1/2 inch wide.
Koch Product 9012	2	6/15/92	467	Sealant was poured early in the morning, ambient temperature was approximately 72°F. No bubbling of the sealant was observed. The width of the joints in this area ranged from 3/8 to 1/2 inch with the majority of joints being 1/2 inch wide.
Koch Product 9050 SL	3	6/01/92	467	Sealant was poured during the evening, the ambient temperature was approximately 78°F. No bubbling was observed during the installation. The joints in this area were approximately 1/2 inch wide.

Table C-2. Sealant Installation Summary For Orlando International Airport Taxiway Area
(Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9015M	4	6/17/92	400	Sealant was poured early in the morning, ambient temperature was approximately 76°F. Some of the sealant material was wasted during the multiple attempts to calibrate the application equipment. This resulted in a shortage of Koch Product 9015M. Therefore, Koch Product 9050 SL was used to seal three of the joints in this section. All of the joints in this area were approximately 1/2 inch wide.
Koch Product 9050 SL	5	6/01/92	467	Sealant was poured during the evening, the ambient temperature was approximately 78°F. No bubbling was observed during the installation. The joints in this area were approximately 1/2 inch wide.
Crafco Superseal 1614A	6	6/05/92	467	Sealant was poured early in the morning, ambient temperature was approximately 72°F. No bubbling was observed during installation. The majority of the joints in this area were approximately 1/2 inch wide. The remaining joints were approximately 5/8 inch wide.

Table C-2. Sealant Installation Summary For Orlando International Airport Taxiway Area
(Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	7	6/15/92	492	This section was originally to receive Koch Product 9015M. However, because of a shortage of material, the majority of the joints were sealed with Dow Corning 888SL. The joints in this area ranged from 1/2 to 5/8 inch wide with the majority being 1/2 inch.
Koch Product 9012	8	6/15/92	530	Sealant was poured early in the morning, ambient temperature was approximately 72°F. Some isolated bubbling of the sealant was observed during installation. The width of the joints in this area ranged from 1/2 to 3/4 inch.
Dow Corning 888SL	9	6/06/92	517	Sealant was poured early in the morning, ambient temperature was approximately 74°F. The joints in this area were approximately 1/2 inch wide.
Crafco Superseal 1614A	10	6/05/92	542	Sealant was poured early in the morning, ambient temperature was approximately 72°F. No bubbling was observed during installation. The majority of the joints in this area were approximately 1/2 inch wide. The remaining joints were approximately 5/8 inch wide.

Table C-3. First Evaluation Summary of Sealant Field Performance at Orlando International Airport.

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Superseal 1614A	Gate G-2	6/05/92	None	None	Bubbling had not increased since installation
	Gate G-8	6/05/92	< 0.5%	None	Same as above.
	Taxiway Area 6	6/05/92	None	None	None
	Taxiway Area 10	6/05/92	None	None	None
Dow Corning 888SL	Gate G-7	6/02/92	None	None	Sealant had discolored, but this did not affect performance.
	Taxiway Area 1	6/02/92	None	None	None
	Taxiway Area 7	6/15/92	None	None	This section had some joints sealed with Koch Product 9015M. The Koch Product 9015M experienced \approx 20% adhesion failure.
	Taxiway Area 9	6/06/92	< 0.5%	None	The adhesive failures only occurred on one side of the pavement.

Table C-3. First Evaluation Summary of Sealant Field Performance at Orlando International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9012	Gate G-3	6/15/92	< 0.5%	None	Only top 1/16 inch of sealant had pulled away from the concrete joint face.
	Gate G-9	6/15/92	None	None	Some fuel had been spilled on isolated areas of the sealant. No fuel-related damage was observed.
	Taxiway Area 2	6/15/92	None	None	N/A
	Taxiway Area 8	6/15/92	None	None	N/A
Koch Product 9015M	Gate G-4	6/17/92	< 0.5%	None	There had been some fuel spillage on the sealant but there was no apparent damage. One area of the sealant had lost some resilience as indicated by the "coin test."
	Gate G-6	6/17/92	≈ 2%	None	Fuel had been spilled in a significant number of the joints. The adhesive failures were in joints that were exposed to fuel spillage

Table C-3. First Evaluation Summary of Sealant Field Performance at Orlando International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M (continued)	Taxiway Area 4	6/17/92	None	None	Some of the joints had been sealed with Koch Product 9050SL. These additional joints did not exhibit any defects.
	Taxiway Area 7	6/17/92	≈ 20%	None	Only 114 linear feet of this section was sealed with Koch Product 9015M.
Koch Product 9050SL	Gate G-5	6/01/92	None	None	A dark film had formed over the sealant surface. A small portion of the sealant had experienced a small amount of swelling. These items did not seem to be affect the field performance of the material.
	Taxiway Area 3	6/01/92	None	None	N/A
	Taxiway Area 5	6/01/92	None	None	N/A

Table C-4. Second Field Evaluation Summary of Sealant Field Performance at Orlando International Airport.

Sealant	Location	Date Sealed	October 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Gate G-2	6/05/92	≈ 3%	None	Some fuel had been spilled in the area which did some damage to the material. Most of the adhesive failure had occurred in the fuel spill area.
	Gate G-8	6/05/92	≈ 11%	None	The adhesive failures were in areas that had been exposed to fuel spillage.
	Taxiway Area 6	6/05/92	None	None	Surface of material had become weathered.
	Taxiway Area 10	6/05/92	None	None	Surface of material had become weathered.
Dow Corning 888SL	Gate G-7	6/02/92	None	None	No change from the March evaluation.
	Taxiway Area 1	6/02/92	None	None	No change from the March evaluation.
	Taxiway Area 7	6/15/92	None	None	No change in the Dow Corning 888SL material from the March evaluation.
	Taxiway Area 9	6/06/92	< 0.5%	None	No change from the March evaluation.

Table C-4. Second Field Evaluation Summary of Sealant Field Performance at Orlando International Airport (Continued).

October 1993 Field Evaluation				
Sealant	Location	Date Sealed	Adhesion	Cohesion
Koch Product 9012	Gate G-3	6/15/92	≈ 1%	None
				Some fuel had been spilled on the pavement. The majority of the adhesive failure was in the fuel spill area. The sealant had become weathered.
	Gate G-9	6/15/92	None	None
	Taxiway Area 2	6/15/92	None	None
Koch Product 9015M	Taxiway Area 8	6/15/92	≈ 0.5%	None
				The sealant had become weathered.
	Gate G-4	6/17/92	> 12%	None
	Gate G-6	6/17/92	*	*
				The adhesive failures generally occurred in the areas that had been exposed to fuel spillage.
				* Aircraft maintenance was being conducted at this gate; therefore, the sealant could not be evaluated.

Table C-4. Second Field Evaluation Summary of Sealant Field Performance at Orlando International Airport (Continued).

Sealant	Location	Date Sealed	October 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M (continued)	Taxiway Area 4	6/17/92	≈ 8%	> 4%	The sealant material had become weathered.
	Taxiway Area 7	6/17/92	≈ 33%	None	Only 114 linear feet of this section was sealed with Koch Product 9015M.
Koch Product 9050SL	Gate G-5	6/01/92	< 0.5%	None	No other changes from the March evaluation.
	Taxiway Area 3	6/01/92	≈ 5%	None	Sealant was discolored in some of the areas that had adhesive failure.
	Taxiway Area 5	6/01/92	< 0.5%	< 0.5%	Sealant had become weathered.

Table C-5. Sealant Installation Summary For Nashville International Airport
Taxiway C-9 Area.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9015M	1 - 1	8/09/92	540	Sealant poured in the morning, ambient temperature was approximately 74°F. Material was tooled with a piece of backer rod because it was not self-leveling. The joints in this area ranged from 3/8 to 1/2 inch wide.
Koch Product 9012	1 - 2	8/08/92	540	Sealant was poured in the morning, ambient temperature was approximately 74°F. The joints in this area ranged from 1/4 to 3/8 inch wide. There was some spalling along the joints.
Crafco Superseal 1614A	1 - 3	8/11/92	540	Sealant was poured in the morning, ambient temperature was approximately 68°F. Some small bubbles did appear during installation. The joints in this area ranged from 1/4 to 3/8 inch wide.

Table C-5. Sealant Installation Summary For Nashville International Airport
Taxiway C-9 Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	1 - 4	8/06/92	540	Joints were sealed early in the morning, ambient temperature was approximately 72°F. The joints in this area were spalled and the width of the joints ranged from 1/4 to 1/2 inch wide.
Koch Product 9050SL	1 - 5	8/04/92	540	Sealant was poured early in the morning, ambient temperature was approximately 68°F. Some small bubbles appeared in the material during installation. The joints in this area ranged from 1/4 to 1/2 inch wide.
Koch Product 9015M	2 - 1	8/09/92	567	Sealant was poured early in the morning, ambient temperature was approximately 74°F. Material did not self-level so a piece of backer rod material was used to smooth the top surface. The joints in this area were approximately 1/4 to 3/8 inch wide.
Koch Product 9012	2 - 2	8/08/92	372	Same notes as listed for Area 1 - 2.

Table C-5. Sealant Installation Summary For Nashville International Airport
Taxiway C-9 Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Crafc Superseal 1614A	2 - 3	8/11/92	540	Same notes as Area 1 - 3.
Dow Corning 888SL	2 - 4	8/06/92	540	Same notes as Area 1 - 4.
Koch Product 9050SL	2 - 5	8/02/92	540	Joints were sealed in the morning, ambient temperature was approximately 60°F. Some bubbles did appear after the installation was completed. The joint width ranged from approximately 1/4 to 3/8 inch wide. Some spalling was evident.

Table C-6. Sealant Installation Summary For Nashville International Airport Gateway Area.

Sealant	Gate Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	C - 6	8/11/92	525	Sealant was poured early in the morning, ambient temperature was approximately 68°F. The joint width in this area ranged from 3/8 to 5/8 inch wide.
Koch Product 9050SL	C - 9	8/05/92	525	Sealant was poured early in the morning, ambient temperature was approximately 68°F. The joints in this area ranged from 3/8 to 1/2 inch wide.
Koch Product 9012	C - 10	8/08/92	525	Sealant was poured early in the morning, ambient temperature approximately 74°F. The joints in this area ranged from 3/8 to 1 inch wide.
Koch Product 9015M	C - 14	8/09/92	525	Same notes as Taxiway C-9 Area 2-1. The width of the joints was approximately 3/8 to 1 inch wide.
Koch Product 9050SL	C - 15	8/04/92	525	Sealant was poured early in the morning, ambient temperature was approximately 68°F. Some bubbling was evident after installation. The joints in this area ranged from 3/8 to 1 1/4 inches wide.
Dow Corning 888SL	C - 16	8/06/92	525	Sealant was poured in the morning, ambient temperature was approximately 69°F. The joints in this area ranged from 3/8 to 1 1/8 inches wide.

Table C-6. Sealant Installation Summary For Nashville International Airport Gateway Area
(Continued).

Sealant	Gate Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	C - 17	8/05/92	525	Sealant was poured in the morning, ambient temperature was approximately 66°F. The joints in this area ranged from 3/8 to 1 inch wide.
Koch Product 9015M	C - 18	8/09/92	525	Sealant was poured in the morning, ambient temperature was approximately 74°F. The joints ranged from 1/2 to 1 1/2 inches wide.
Crafco Superseal 1614A	C - 19	8/11/92	525	Sealant was installed in the morning, ambient temperature was approximately 68°F. The width of the joints ranged from 3/8 to 1 inch wide. Some of the joints were spalled.
Koch Product 9012	C - 20	8/08/92	525	Sealant was poured early in the mor- ning, ambient temperature was ap- proximately 74°F. The width of the joints in this area ranged from 3/8 to 5/8 inch wide.

Table C-7. First Evaluation Summary of Sealant Field Performance at Nashville International Airport.

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Gate C-6	8/11/92	None	None	N/A
	Gate C-19	8/11/92	≈ 10%	None	Some fuel had been spilled in the area but this did not appear to affect the performance of the sealant. There was some joint spalling in the area.
	Taxiway Area 1-3	8/11/92	None	None	N/A
	Taxiway Area 2-3	8/11/92	None	None	The sealant had 1 to 2 bubbles per linear foot. The diameter of the bubbles was < 1/8 inch.
Dow Corning 888SL	Gate C-17	8/05/92	None	None	Some fuel had been spilled in the area but this spillage did not appear to affect the performance of the sealant.
	Gate C-16	8/06/92	< 0.5%	None	The adhesive failures were associated with joint spalling.

Table C-7. First Evaluation Summary of Sealant Field Performance at Nashville International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Dow Corning 888SL	Taxiway Area 1-4	8/06/92	None	None	N/A
	Taxiway Area 2-4	8/06/92	None	None	N/A
Koch Product 9012	Gate C-10	8/08/92	< 1%	None	There was old sealant material in the joints where adhesive failures were noted. Fuel spillage had occurred in the area but it did not appear to affect the performance of the sealant.
	Gate C-20	8/08/92	None	None	Some fuel had been spilled in the area but it did not appear to affect the performance of the sealant.
	Taxiway Area 1-2	8/08/92	None	None	N/A
	Taxiway Area 2-2	8/08/92	None	None	N/A

Table C-7. First Evaluation Summary of Sealant Field Performance at Nashville International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M	Gate C-14	8/05/92	< 5%	None	The adhesive failure occurred in an area that had been exposed to fuel spillage.
	Gate C-18	8/09/92	< 5%	None	The adhesive failure occurred in an area that was spalled.
	Taxiway Area 1-1	8/09/92	None	None	N/A
	Taxiway Area 2-1	8/09/92	None	None	N/A
Koch Product 9050SL	Gate C-9	8/05/92	None	None	N/A
	Gate C-15	8/04/92	None	None	Some fuel had been spilled in the area but this did not appear to affect the performance of the sealant.
	Taxiway Area 1-5	8/04/92	None	None	The sealant had lost some resilience as indicated by the coin test.
	Taxiway Area 2-5	8/02/92	None	None	N/A

Scheduling conflicts and poor weather conditions prevented additional evaluations.

Table C-8. Sealant Installation Summary For Albuquerque International Airport Ramp Area.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9012	1	6/30/92	525	Sealant poured in the morning, ambient temperature was approximately 75°F. Some random surface bubbling was noticed during installation. The joints in this area were approximately 3/4 to 1 1/4 inches wide.
Dow Corning 888SL	2	7/01/92	525	Sealant was poured in the afternoon, ambient temperature was approximately 95°F. The material was sprayed with a water mist to initiate curing. Low humidity conditions retarded the curing mechanism. The joints in this area ranged from 1/4 to 7/8 inch wide.
Koch Product 9050SL	3	7/01/92	525	Sealant was poured in the evening, ambient temperature was approximately 70°F. The material was sprayed with a water mist to initiate curing. Low humidity conditions retarded the curing mechanism. The joints in this area ranged from 3/4 to 7/8 inch wide.
Crafco Superseal 1614A	4	7/02/92	525	Joints were sealed in the afternoon, ambient temperature was approximately 88°F. The joints in this area were approximately 1/2 to 7/8 inch wide.

Table C-8. Sealant Installation Summary For Albuquerque International Airport Ramp Area
(Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9015M	5	7/02/92	450	Sealant was poured in the evening, ambient temperature was approximately 70°F. The joints in this area were approximately 1/2 to 7/8 inch wide.
Dow Corning 888SL	6	7/01/92	450	Same notes as listed for Ramp Area 2.
Koch Product 9012	7	6/30/92	525	Same notes as listed for Ramp Area 1.
Koch Product 9015M	8	7/01/92	650	Same notes as listed for Ramp Area 5.
Koch Product 9050SL	9	7/01/92	525	Same notes as listed for Ramp Area 3.
Crafco Superseal 1614A	10	7/02/92	525	Same notes as listed for Ramp Area 4.

Table C-9. Sealant Installation Summary For Albuquerque International Airport Runway 17.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9012	1	6/30/92	425	Sealant was installed in the morning, ambient temperature was approximately 75°F. Some surface bubbling occurred during the installation of the sealant. The width of the joints ranged from 1/2 to 3/4 inch.
Koch Product 9050SL	2	6/27/92	525	Sealant was poured in the afternoon, ambient temperature was approximately 90°F. The sealant did not skin over. A light water mist was sprayed over the sealant to initiate cure. Some of the material was tracked out of the joint over the next two days. The joint width in this area ranged from 1/2 to 7/8 inch wide.
Dow Corning 888SL	3	6/29/92	525	Sealant was poured in the evening, ambient temperature approximately 80°F. A water mist was used to initiate the curing mechanism. The joints in this area were approximately 1/2 to 5/8 inch wide.

Table C-9. Sealant Installation Summary For Albuquerque International Airport Runway 17
(Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	4	7/02/92	525	Same notes as listed for Ramp Area 4.
Koch Product 9015M	5	7/02/92	525	Same notes as listed for Ramp Area 5.
Koch Product 9012	6	6/30/92	525	Same notes as listed for Ramp Area 1 except the bubbling was located predominately in the longitudinal joints.
Koch Product 9050SL	7	6/27/92	525	Same notes as Runway 17 Area 2. Sealant developed a surface skin within three days but aircraft tracked the material onto the pave- ment surface.
Dow Corning 888SL	8	6/30/92	525	Same notes as for Runway 17 Area 3.
Crafco Superseal 1614A	9	7/02/92	350	Same notes as listed for Ramp Area 4.
Koch Product 9015M	10	7/02/92	350	Same notes as listed for Ramp Area 5.

Table C-10. First Evaluation Summary of Sealant Field Performance at Albuquerque International Airport.

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Runway 17 Area 4	7/02/92	< 11%	None	Surface bubbles and surface cracking were noted in the sealant.
	Runway 17 Area 9	7/02/92	> 11%	> 11%	Surface bubbles and surface cracking were noted in the sealant. The adhesive and cohesive failures are located randomly throughout the section.
	Ramp Area 4	7/02/92	None	None	Surface bubbles and surface cracking were noted in the sealant. Fuel had been spilled in various areas of this section.
	Ramp Area 10	7/02/92	< 11%	< 11%	Surface bubbles and surface cracking were noted in the sealant. Fuel had been spilled in several areas of this section.
Dow Corning 888SL	Runway 17 Area 3	6/29/92	None	None	N/A
	Runway 17 Area 8	6/30/92	None	None	The sealant exhibited some surface cracking, potentially indicating weathering.

Table C-10. First Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant		Location	Date Sealed	March 1993 Field Evaluation		
				Adhesion	Cohesion	Other
Dow Corning 888SL	Ramp Area 2		7/01/92	None	None	N/A
	Ramp Area 6		7/01/92	None	None	N/A
Koch Product 9012	Runway 17 Area 1		6/30/92	None	None	The surface of the sealant had surface cracking and some random bubbling. The surface cracking is a potential indication of weathering.
	Runway 17 Area 6		6/30/92	< 11%	< 11%	The adhesive and cohesive failures occurred randomly throughout the section. The sealant had some random surface bubbling and surface cracking.
	Ramp Area 1		6/30/92	None	< 11%	The surface of the sealant had some random bubbling and cracking. This potentially indicates weathering of the material.
	Ramp Area 7		6/30/92	None	< 1%	Some fuel had been spilled in the area but the spillage did not appear to affect the performance of the sealant. The surface of the sealant had some random bubbling and cracking, potentially indicating weathering.

Table C-10. First Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M	Runway 17 Area 5	7/02/92	None	None	The surface of the sealant exhibited some cracking which could indicate weathering.
	Runway 17 Area 10	7/02/92	None	None	The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 5	7/02/92	None	None	The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 8	7/02/92	< 11%	< 11%	Fuel had been spilled in the area which appeared to contribute to some of the failures. The surface of the sealant exhibited some cracking indicating potential weathering.

Table C-10. First Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9050SL	Runway 17 Area 2	6/27/92	None	None	The surface of the sealant exhibited some cracking which could indicate weathering.
	Runway 17 Area 7	6/27/92	< 11%	< 11%	The adhesive and cohesive failures were random throughout the section. The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 3	7/01/92	None	None	The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 9	7/01/92	None	None	There was some fuel spillage in the area but it did not appear to be affecting the performance of the sealant.

Table C-11. Second Evaluation Summary of Sealant Field Performance at Albuquerque International Airport.

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Runway 17 Area 4	7/02/92	< 11%	> 50%	The cohesive failures were noted throughout the section.
	Runway 17 Area 9	7/02/92	> 11%	> 50%	The cohesive failures were noted throughout the section.
	Ramp Area 4	7/02/92	< 11%	< 11%	Surface bubbles and surface cracking were noted in the sealant. Fuel had been spilled in various areas of this section.
	Ramp Area 10	7/02/92	< 11 %	< 11%	Surface bubbles and surface cracking were noted in the sealant. The sealant had lost some resilience as indicated by the coin test.
Dow Corning 888SL	Runway 17 Area 3	6/29/92	None	None	N/A
	Runway 17 Area 8	6/30/92	None	None	N/A

Table C-11. Second Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Dow Corning 888SL	Ramp Area 2	7/01/92	None	None	N/A
	Ramp Area 6	7/01/92	None	None	N/A
Koch Product 9012	Runway 17 Area 1	6/30/92	< 11%	< 11%	The surface of the sealant had surface cracking and some random bubbling. The adhesive and cohesive failures were located randomly throughout the section.
	Runway 17 Area 6	6/30/92	< 11%	> 11%	The adhesive and cohesive failures occurred randomly throughout the section. The sealant had some random surface bubbling and surface cracking.
	Ramp Area 1	6/30/92	None	< 11%	The surface of the sealant had some random bubbling and cracking. This potentially indicates weathering of the material.
	Ramp Area 7	6/30/92	None	< 1%	N/A

Table C-11. Second Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M	Runway 17 Area 5	7/02/92	< 11%	< 11%	The surface of the sealant exhibited some cracking which could indicate weathering.
	Runway 17 Area 10	7/02/92	> 11%	> 11%	The adhesive and cohesive failures were located throughout the section. Some fuel had been spilled in the area.
	Ramp Area 5	7/02/92	< 11%	< 11%	The surface of the sealant exhibited some cracking which could indicate weathering. There had been some fuel spillage in the area.
	Ramp Area 8	7/02/92	> 11%	> 11%	The adhesive and cohesive failures were located throughout the section. There had been fuel spillage in several areas of the section which contributed to the failures.

Table C-11. Second Evaluation Summary of Sealant Field Performance at Albuquerque International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9050SL	Runway 17 Area 2	6/27/92	None	> 11%	The cohesive failures were located throughout the section.
	Runway 17 Area 7	6/27/92	< 11%	< 11%	The adhesive and cohesive failures were random throughout the section. The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 3	7/01/92	None	> 11%	The surface of the sealant exhibited some cracking which could indicate weathering.
	Ramp Area 9	7/01/92	< 11%	> 11%	There was a considerable amount of debris in the joints. There was some fuel spillage in the area.

Table C-12. Sealant Installation Summary For Reno-Cannon International Airport Taxiway B.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9015M	1	7/16/92	310	Sealant poured in the early morning, ambient temperature was approximately 58°F. Material was tooled with a piece of backer rod because it was not self-leveling. The joints in this area were approximately 3/4 inch wide.
Dow Corning 888SL	2	7/11/92	310	Sealant was poured in the morning, ambient temperature was approximately 53°F. The joints in this area ranged from 1/2 to 3/4 inch wide.
Crafco Superseal 1614A	3	7/11/92	310	Sealant was poured in the early morning, ambient temperature was approximately 53°F. Some small bubbles did appear during installation. The sealant temperature during application was approximately 250°F.
Koch Product 9012	4	7/14/92	310	Joints were sealed early in the morning, ambient temperature was approximately 57°F. The sealant temperature during application was approximately 260°F. There was a significant amount of surface bubbling in the sealant. The joints in this area were approximately 3/4 inch wide.

Table C-12. Sealant Installation Summary For Reno-Cannon International Airport Taxiway B
(Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9050SL	5	7/14/92	310	Sealant was poured in the morning, ambient temperature was approximately 57°F. The material had not begun to skin over within two to three hours so a water mist was sprayed on the material to initiate cure. The joints in this area were approximately 3/4 inch wide.
Dow Corning 888SL	6	7/11/92	310	Same notes as Taxiway B Area 2.
Koch Product 9015M	7	7/16/92	310	Same notes as listed for Taxiway B Area 1.
Koch Product 9050SL	8	7/14/92	310	Same notes as listed for Taxiway B Area 5.
Crafco Superseal 1614A	9	7/11/92	310	Same notes as listed for Taxiway B Area 3. Sealant temperature during application was approximately 210°F.
Koch Product 9012	10	7/14/92	385	Joints were sealed in the early morning, ambient temperature was approximately 57°F. Some bubbles did appear after the installation was completed. The sealant temperature during application was approximately 240°F. The joint width ranged from approximately 1/4 to 3/8 inch wide. Some spalling was evident.

Table C-13. Sealant Installation Summary For Reno-Cannon International Airport North Ramp.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	1	7/12/92	700	Sealant was installed early in the morning, ambient temperature was approximately 55°F. One area of this section had been exposed to repeated fuel spillage as indicated by stains on the concrete. There was a small amount of surface bubbling that occurred during installation. The temperature of the sealant was 280°F during installation. The width of the joints ranged from 1/2 to 3/4 inch.
Koch Product 9050SL	2	7/10/92	675	Sealant was poured early in the morning, ambient temperature was approximately 56°F. The sealant did not skin over within 3 hours. A light water mist was sprayed over the sealant to initiate cure. After 48 hours, there was a thin skin over the material. One portion of the pavement had been exposed to fuel spillage and the pavement was stained. The joints were approximately 1/2 to 3/4 inch wide.

Table C-13. Sealant Installation Summary For Reno-Cannon International Airport
North Ramp (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9015M	3	7/16/92	700	Sealant was poured late at night, ambient temperature approximately 58°F. The joints in this area were approximately 1/2 inch wide. The sealant did not self-level in some areas therefore it was smoothed with a piece of backer rod.
Dow Corning 888SL	4	7/11/92	700	Sealant was poured early in the morning, ambient temperature was approximately 53°F. The shape factor of the sealant varied due to non-uniform joint dimensions. The joint width in this area was approximately 3/4 inch.
Koch Product 9012	5	7/14/92	600	Sealant was poured early in the morning, ambient temperature was approximately 57°F. The sealant temperature was 290°F during installation. The joints in this area ranged from 1/2 to 3/4 inch wide.
Koch Product 9015M	6	7/16/92	600	Sealant was poured in the morning, ambient temperature was approximately 58°F. The joints in this area ranged from 1/2 to 3/4 inch wide.

Table C-13. Sealant Installation Summary For Reno-Cannon International Airport
North Ramp (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	7	7/11/92	700	Same notes as Taxiway B Area 2.
Koch Product 9012	8	7/14/92	700	Sealant was poured in the early morning, ambient temperature was approximately 57°F. The sealant temperature during installation was 280°F. Some surface bubbling did occur during installation. The joints ranged from 1/2 to 3/4 inch wide.
Koch Product 9050SL	9	7/10/92	700	Same note as listed for North Ramp Area 2.
Crafco Superseal 1614A	10	7/12/92	700	Sealant was poured early in the early morning, ambient temperature was approximately 55°F. The temperature of the sealant was approximately 260°F during application. The width of the joints in this area ranged from 1/2 to 3/4 inch wide.

Table C-14. First Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport.

Sealant		Location	Date Sealed	March 1993 Field Evaluation		
				Adhesion	Cohesion	Other
Crafco Super-seal 1614A		Taxiway B Area 3	7/11/92	≈ 48%	None	Surface bubbles and surface cracking were noted in the sealant. The adhesive failures are predominately located in the transverse joints.
		Taxiway B Area 9	7/11/92	≈ 48%	None	Surface bubbles and surface cracking were noted in the sealant. The adhesive failures are located predominately in the transverse joints.
		North Ramp Area 1	7/11/92	< 11%	< 11%	Surface bubbles and surface cracking were noted in the sealant. Fuel had been spilled in various areas of this section.
		North Ramp Area 10	7/12/92	> 11 %	> 11%	Surface bubbles and surface cracking were noted in the sealant.
Dow Corning 888SL		Taxiway B Area 2	7/11/92	< 0.5%	None	The sealant had become discolored in some areas. The discoloration was probably caused by blowing dust and debris.
		Taxiway B Area 6	7/11/92	None	None	N/A

Table C-14. First Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant		Location	Date Sealed	March 1993 Field Evaluation		
				Adhesion	Cohesion	Other
Dow Corning 888SL		North Ramp Area 4	7/11/92	< 0.5%	None	Some fuel had been spilled in the area, but the performance of the sealant did not appear to be affected.
		North Ramp Area 7	7/11/92	None	None	The surface of the sealant had some crazing, potentially indicating weathering.
Koch Product ⁺ 9012		Taxiway B Area 4	7/14/92	≈ 48%	None	The surface of the sealant had surface cracking and some random bubbling. The surface cracking is a potential indication of weathering. The majority of adhesive failure is located in the transverse joints.
		Taxiway B Area 10	7/14/92	≈ 45%	< 6%	The adhesive and cohesive failures occurred in the transverse joints. The sealant had some random surface bubbling and surface cracking.
		North Ramp Area 5	7/14/92	None	< 1%	The surface of the sealant had some random bubbling and cracking. This potentially indicates weathering of the material.

Table C-14. First Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9012 (continued)	North Ramp Area 8	7/14/92	None	< 1%	Some fuel had been spilled in the area but the spillage did not appear to affect the performance of the sealant. The surface of the sealant had some random bubbling and cracking, potentially indicating weathering.
	Taxiway B Area 1	7/16/92	≈ 50%	> 11%	The adhesive and cohesive failures were random throughout the section. The surface of the sealant exhibited some cracking which could indicate weathering. The sealant also had some bubbling and swelling.
Koch Product 9015M	Taxiway B Area 7	7/16/92	≈ 50%	> 11%	Same notes as listed for Taxiway B Area 1.
	North Ramp Area 3	7/16/92	< 11%	< 11%	There was some fuel spillage in the area. Also some joints were spalled. The adhesive and cohesive failures were random throughout the section.
	North Ramp Area 6	7/16/92	< 11%	< 1%	Same as North Ramp Area 3.

Table C-14. First Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9050SL	Taxiway B Area 5	7/14/92	> 11%	< 11%	The adhesive and cohesive failures were random throughout the section.
	Taxiway B Area 8	7/14/92	< 11%	< 11%	The adhesive and cohesive failures were random throughout the section.
	North Ramp Area 2	7/10/92	< 11%	None	There was some fuel spillage in the area. The sealant did exhibit some bubbling and swelling. Approximately 100 linear feet of the joints had become spalled. The sealant had lost some resilience as indicated by the coin test.
	North Ramp Area 9	7/10/92	None	None	There was some fuel spillage in the area but it did not appear to be affecting the performance of the sealant.

Table C-15. Second Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport.

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Taxiway B Area 3	7/11/92	> 50%	< 11%	Surface bubbles and surface cracking were noted in the sealant. The adhesive failures are predominately located in the transverse joints.
	Taxiway B Area 9	7/11/92	> 50%	> 50%	Surface bubbles and surface cracking were noted in the sealant. The adhesive failures were located throughout the section.
	North Ramp Area 1	7/11/92	> 50%	> 50%	Surface bubbles and surface cracking were noted in the sealant. Fuel had been spilled in various areas of this section. The adhesive and cohesive failures were located throughout the section.
	North Ramp Area 10	7/12/92	> 11 %	> 11%	Surface bubbles and surface cracking were noted in the sealant.
Dow Corning 888SL	Taxiway B Area 2	7/11/92	< 11%	None	N/A
	Taxiway B Area 6	7/11/92	< 5%	None	N/A

Table C-15. Second Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Dow Corning 888SL	North Ramp Area 4	7/11/92	< 1%	None	N/A
	North Ramp Area 7	7/11/92	None	None	N/A
Koch Product 9012	Taxiway B Area 4	7/14/92	> 50%	> 11%	The majority of adhesive and cohesive failures were located in the transverse joints.
	Taxiway B Area 10	7/14/92	> 50%	> 50%	The adhesive and cohesive failures were present throughout the section.
	North Ramp Area 5	7/14/92	< 5%	< 5%	There had been some fuel spillage in the area but this did not seem to affect the performance of the sealant.
	North Ramp Area 8	7/14/92	None	< 1%	Some fuel had been spilled in the area but the spillage did not appear to affect the performance of the sealant. The surface of the sealant had some random bubbling and cracking, potentially indicating weathering.

Table C-15. Second Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M	Taxiway B Area 1	7/16/92	> 50%	> 11%	The adhesive and cohesive failures were random throughout the section.
	Taxiway B Area 7	7/16/92	> 50%	> 11%	Same notes as listed for Taxiway B Area 1.
	North Ramp Area 3	7/16/92	> 11%	< 11%	There was some fuel spillage in the area. Also some joints were spalled. The adhesive and cohesive failures were random throughout the section.
	North Ramp Area 6	7/16/92	< 11%	< 1%	Same as North Ramp Area 3.

Table C-15. Second Evaluation Summary of Sealant Field Performance at Reno-Cannon International Airport (Continued).

Sealant	Location	Date Sealed	November 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9050SL	Taxiway B Area 5	7/14/92	> 11%	< 11%	The adhesive and cohesive failures were random throughout the section.
	Taxiway B Area 8	7/14/92	> 11%	< 11%	The adhesive and cohesive failures were random throughout the section.
	North Ramp Area 2	7/10/92	< 11%	< 1%	N/A
	North Ramp Area 9	7/10/92	< 11%	< 1%	N/A

Table C-16. Sealant Installation Summary For Selfridge Air National Guard Base Fuel Storage Area.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9050SL	1	8/25/92	474	Joints were sealed early in the morning, ambient temperature was approximately 70°F. The joints in this area were approximately 3/8 inch wide.
Koch Product 9015M	2	9/02/92	480	Joints sealed early in the morning, ambient temperature was approximately 57°F. The joints in this area were approximately 3/8 inch wide.
Crafco Superseal 1614A	3	8/31/92	330	Joints sealed early in the morning, ambient temperature was approximately 56°F. Two hundred thirty feet of joints in this section were sealed with Koch Product 9050SL due to a lack of material. The sealant did exhibit some bubbling during installation. This was the last section sealed with the Crafco Superseal 1614; therefore, the bubbling could have been caused by insufficient material in the melter. The joints in this area were approximately 3/8 inch wide.

Table C-16. Sealant Installation Summary For Selfridge Air National Guard Base Fuel Storage Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	4	8/23/92	478	Sealant was poured early in the morning, ambient temperature was approximately 70°F. The joints in this area were approximately 3/8 inch wide.
Koch Product 9050SL	5	8/25/92	540	Same notes as listed for Area 1. The joints in this area were approximately 3/8 inch wide.
Koch Product 9012	6	8/30/92	620	Sealant was poured early in the morning, ambient temperature was approximately 62°F. No bubbling was observed during installation. The joints in this area were approximately 3/8 inch wide.
Koch Product 9012	7	8/30/92	372	Same notes as listed for Area 6.

Table C-17. Sealant Installation Summary For Selfridge Air National Guard Base Taxiway F Area.

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	1	8/30/92	490	Sealant was poured early in the morning, ambient temperature was approximately 62°F. The joints in this area ranged from 5/8 to 1 1/4 inches wide.
Dow Corning 888SL	2	8/22/92	505	Sealant was poured early in the morning, ambient temperature was approximately 52°F. The joints in this area ranged from 5/8 to 7/8 inch wide. The majority of the joints were approximately 5/8 inch wide.
Koch Product 9015M	3	9/01/92	500	Temperature during sealant application was 54°F. The cure of the material appeared to be retarded by the cool temperature. The sealant remained tacky to the touch through the morning but was tack free by the afternoon. The joint width in this area was approximately 5/8 inch wide.

Table C-17. Sealant Installation Summary For Selfridge Air National Guard Base
Taxiway F Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Koch Product 9050SL	4	8/25/92	520	Sealant was poured early in the morning, ambient temperature was approximately 68°F. It rained late in the evening, but there was no apparent damage to the material. The joint width in this area ranged from 1/2 to 5/8 inch.
Koch Product 9012	5	8/30/92	500	Sealant was poured early in the morning, ambient temperature approximately 66°F. The joints in this area ranged from 1/2 to 1 inch wide.
Crafco Superseal 1614A	6	8/31/92	500	Sealant was poured early in the morning, ambient temperature was approximately 60°F. The width of the joints was approximately 5/8 inch.

Table C-17. Sealant Installation Summary For Selfridge Air National Guard Base
Taxiway F Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Dow Corning 888SL	7	8/22/92	495	Sealant was installed in the morning, ambient temperature was approximately 65°F. The width of the joints ranged from 3/4 to 7/8 inch.
Koch Product 9015M	8	9/02/92	522	Sealant was poured early in the morning, ambient temperature was approximately 58°F. The width of the joints in this area ranged from 3/4 to 5/8 inch.
Koch Product 9050SL	9	8/25/92	498	Sealant was poured in the morning, ambient temperature was approximately 67°F. The joints in this area ranged from 5/8 to 3/4 inch. The majority of the joints were 5/8 inch.
Koch Product 9012	10	8/30/92	534	Sealant was poured early in the morning, ambient temperature was approximately 66°F. The joints in this area ranged from 5/8 to 3/4 inch.
Dow Corning 888SL	11	8/25/92	503	Sealant was poured early in the morning, ambient temperature was approximately 67°F. The majority of the joints in this area were 5/8 inch. One joint was 3/4 inch wide.

Table C-17. Sealant Installation Summary For Selfridge Air National Guard Base
Taxiway F Area (Continued).

Sealant	Area Number	Date Sealed	Linear Feet Sealed	General Comments
Crafco Superseal 1614A	12	8/31/92	509	Sealant was poured early in the morning, ambient temperature was approximately 60°F. The joints in this area ranged from 1/2 to 5/8 inch wide.
Koch Product 9015M	13	9/02/92	447	Joints sealed early in the morning, ambient temperature was approximately 58°F. The hose connection for Component B was loose and some material leaked. The joints in this area ranged from 1/2 to 5/8 inch wide.

Table C-18. First Evaluation Summary of Sealant Field Performance at Selfridge.

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Taxiway F Area 1	8/30/92	None	None	Sealant material exhibited some bubbling, approximately 1 to 5 bubbles per linear foot. The diameter of the bubbles was less than 1/8 inch.
	Taxiway F Area 6	8/31/92	< 5%	< 5%	The loss of adhesion was generally isolated to the top 1/16 to 1/8 inch of the sealant surface. All adhesive and cohesive failures were located in the transverse joints.
	Taxiway F Area 12	8/31/92	< 11%	< 11%	Adhesive and cohesive failures occurred in all joints.
	Fuel Area 3	8/31/92	None	< 1%	The sealant had 3 to 4 bubbles per foot. The diameter of the bubbles was < 1/8 inch. Portions of this section were sealed with Koch Product 9050SL.
Dow Corning 888SL	Taxiway F Area 2	8/22/92	< 0.5%	None	The joint had spalled in the area where the adhesive failure had occurred. It is assumed that the spalling caused the adhesive failure.
	Taxiway F Area 7	8/22/92	None	None	N/A

Table C-18. First Evaluation Summary of Sealant Field Performance at Selfridge
(Continued).

Sealant	Location	Date Sealed	March 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Dow Corning 888SL	Taxiway F Area 11	8/25/92	None	None	N/A
	Fuel Area 4	8/23/92	None	None	N/A
Koch Product 9012	Taxiway F Area 5	8/30/92	<11%	None	There was old sealant material in the joints where adhesive failures were noted. There was approximately 2 to 3 bubbles per linear foot with diameters less than 1/4 inch.
	Taxiway F Area 10	8/30/92	< 1%	None	Old sealant material was in the joints where adhesive failure occurred. There was approximately 2 to 3 bubbles per linear foot with diameters ranging up to 1/4 inch.
	Fuel Area 6	8/30/92	None	None	There had been a fuel spillage on one portion of the test area. There was no apparent damage caused by the fuel spill.
	Fuel Area 7	8/30/92	None	None	N/A

Table C-18. First Evaluation Summary of Sealant Field Performance at Selfridge
(Continued).

Sealant		Location	Date Sealed	March 1993 Field Evaluation		
				Adhesion	Cohesion	Other
Koch Product 9015M		Taxiway F Area 3	9/01/92	None	None	The sealant was tacky underneath the top skin. The material had been slow to cure during installation.
		Taxiway F Area 8	9/02/92	>0.5%	None	There was old sealant material in the joint where the adhesive failure occurred.
		Taxiway F Area 13	9/02/92	None	None	N/A
		Fuel Area 2	9/02/92	None	None	N/A
Koch Product 9050SL		Taxiway F Area 4	8/25/92	< 11%	None	Some but not all of the adhesive failures could be attributed to old sealant in the joint.
		Taxiway F Area 9	8/25/92	<1%	None	Adhesive failure potentially caused by old sealant in the joint.
		Fuel Area 1	8/25/92	None	None	N/A
		Fuel Area 3	8/31/92	None	None	N/A
		Fuel Area 5	8/25/92	None	None	N/A

Table C-19. Second Evaluation Summary of Sealant Field Performance at Selfridge Air National Guard Base.

Sealant	Location	Date Sealed	October 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Crafco Super-seal 1614A	Taxiway F Area 1	8/30/92	<5%	None	The severity of bubbling did not appear to have increased. There was some joint spalling. The sealant had lost some resilience as indicated by the "coin test."
	Taxiway F Area 6	8/31/92	≈ 10%	≈ 10%	Adhesive and cohesive failures were located in the transverse joints. The joints had experienced some spalling. The sealant had weathered as indicated by surface cracking.
	Taxiway F Area 12	8/31/92	< 11%	< 11%	Adhesive and cohesive failures had not greatly increased since the March evaluation. There was some joint spalling.
	Fuel Area 3	8/31/92	None	< 1%	The severity of the bubbling did not appear to have increased since the March evaluation.
Dow Corning 888SL	Taxiway F Area 2	8/22/92	< 1%	None	The joint spalling in the area had increased. The adhesive failures were generally associated with the spalling.
	Taxiway F Area 7	8/22/92	< 1%	None	Joint spalling had occurred in this area and most failures were associated with the spalling.

Table C-19. Second Evaluation Summary of Sealant Field Performance at Selfridge
Air National Guard Base (Continued).

Sealant	Location	Date Sealed	October 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9015M	Taxiway F Area 3	9/01/92	< 5%	None	Some joint spalling had occurred in the area. The adhesive failures were generally associated with the joint spalling.
	Taxiway F Area 8	9/02/92	< 5%	None	There was old sealant material in the joint where the adhesive failure occurred. Some spalling had also occurred.
	Taxiway F Area 13	9/02/92	≈ 40%	< 11%	Portions of the adhesive failure could be associated joint spalling, however, the majority adhesive failures were not in spalled areas.
	Fuel Area 2	9/02/92	< 5%	< 5%	N/A
Koch Product 9050SL	Taxiway F Area 4	8/25/92	> 50%	None	Area had a significant amount of adhesive failing. There was some joint spalling in the area but not a significant amount.
	Taxiway F Area 9	8/25/92	> 50%	None	Material had become hard as indicated by "coin test."
	Fuel Area 1	8/25/92	< 5%	None	There was some fuel spillage in the area. The sealant exposed to the fuel had lost some resilience as indicated by the "coin test."

Table C-19. Second Evaluation Summary of Sealant Field Performance at Selfridge
Air National Guard Base (Continued).

Sealant	Location	Date Sealed	October 1993 Field Evaluation		
			Adhesion	Cohesion	Other
Koch Product 9050SL (con- tinued)	Fuel Area 3	8/31/92	None	None	N/A
	Fuel Area 5	8/25/92	< 5%	None	N/A